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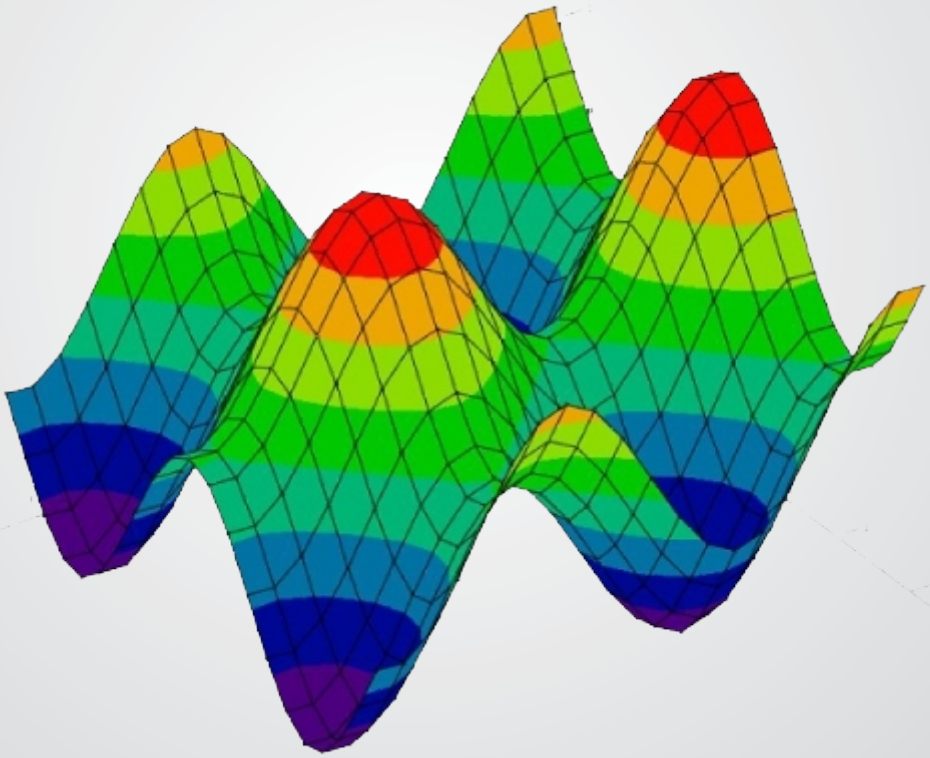

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CONTENTS

DETERMINATION OF TENSION OF FILM DURING THE WRAPPING OF PALLET POUCH

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Abstract. *The features of the dynamics of wrapping of pallet pouch with film in conditions of stabilization of speed of film spooling were examined. There with variable stiffness of film's working area remains as destabilizing parameter.*

Keywords: pallet, film, kinematic parameters, wrapping, bobbin

I. Introduction

Known shortcomings of mechanical wrapping of pallet pouch with film is the irregularity of its tension. Sometimes there is no tension at all, i.e. the film sags. In consequence of that, you cannot reach your programmed stability of pallet pouch, you lose finished products and have to perform some operations manually, etc. [1].

Irregular tension is the result of variable speed of film spooling from bobbin and changeable length of film between drive member and driven member. Kinematic perturbation of the "package tray – film – bobbin" were evaluated previously [2, 3], however, the impact of dynamics of the process of film's variable stiffness deserves special attention. This is even more topical because one of the directions of problem solving is to stabilize the speed of film spooling by using an adjustable pallet pouch.

II. Materials and methods

Consider the case when speed $\dot{x}^{I}_{ст}$ of film spooling is a constant value. This can be reached if the angular velocity $\omega = \omega($ of the pallet pouch is variable. Figure 1 shows a scheme of the device for wrapping the pallet pouch.

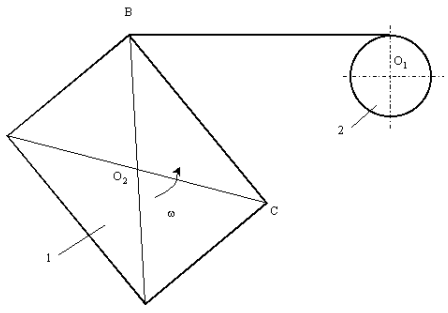

Figure 1. *Scheme of the device for wrapping a package tray of film: 1 – package tray; 2 – bobbin of film*

Since the length of its facets is various, we distinguish two phases of movement. Film interacts with the edge B on the first stage, on the second stage it interacts with the edge C. Composing model of transition stage, we assume that the leading mass during the selection of process clearance attains speed $\dot{x}^{I}_{ст}$ of film spooling. Then the equation of motion of driving and driven masses is:

$$\begin{cases} x_1 = \dot{x}^{I}_{ст} t + x^{I}_{1(n)}; \\ m_2 \ddot{x}_2 = c(x_1 - x_2) - P_{оп}, \end{cases} \qquad (2.1)$$

where x_1 and x_2 are coordinates of the movement of driving and driven masses, respectively, m; c – is unit stiffness of system, N/m; $P_{оп}$ – is reduced resistance force of the driving mass, N.

We specify unit stiffness by division of specific stiffness EF (where E is modulus of elasticity of the material of film, Pa; F – is cross-sectional area of the film, m^2) to the total length l of the section of film between the edge of the pallet pouch and bobbin.

Substitution of the values of stiffness c (with a glance $l = x_1$) and x_1 transforms an equation (1) into the expression:

$$\ddot{x}_2 = \frac{EF}{m_2} - \frac{EF\, x_2}{m_2(\dot{x}^{I}_{ст} t + x^{I}_{1(n)})} - \frac{P_{оп}}{m_2} \qquad (2.2)$$

The initial conditions of the first stage are:

$$t^{I}_{(n)} = 0;\ x^{I}_{2(n)} = x^{I}_{1(n)} - \frac{P_{оп}}{EF} x_1;\ \dot{x}^{I}_{2(n)} = \dot{x}^{I}_{ст}. \qquad (2.3)$$

Integration of the expression (2) allows to determinate kinematic parameters depending on time

and substitution of time of the end of the first stage $t = t^{I}_{(к)}$ makes it possible to calculate the values of kinematic parameters $x^{I}_{2(к)}$, $\dot{x}^{I}_{2(к)}$, $\ddot{x}^{I}_{2(к)}$.

The equation of movement for the second phase is:

$$\begin{cases} x_1 = \dot{x}^{II}_{ст} t + x^{II}_{1(п)}; \\ m_2 \ddot{x}_2 = c(x_1 - x_2) - P_{оп}. \end{cases} \quad (2.4)$$

After substituting the values c and x_1 and after the transformations we get:

$$\ddot{x}_2 = \frac{EF}{m_2} - \frac{EF\, x_2}{m_2(\dot{x}^{II}_{ст} t + x^{II}_{1(п)})} - \frac{P_{оп}}{m_2}. \quad (2.5)$$

The initial conditions of the second stage are:

$$t^{II}_{(п)} = 0; \quad x^{II}_{2(п)} = x^{I}_{2(к)}; \quad \dot{x}^{II}_{2(п)} = \dot{x}^{I}_{2(к)}. \quad (2.6)$$

Springy forces in film on the first and second stages are determined by expressions:

$$P^{I}_{пр} = \frac{EF}{\dot{x}^{I}_{ст} t + x^{I}_{1(п)}} (x^{I}_1 - x^{I}_2), \quad (2.7)$$

$$P^{II}_{пр} = \frac{EF}{\dot{x}^{II}_{ст} t + x^{II}_{1(п)}} (x^{II}_1 - x^{II}_2). \quad (2.8)$$

If the speed of film spooling is constant than the extrinsic perturbations of oscillation processes disappear. However, stiffness of the film remains variable, and that continues to destabilize springy forces.

III. Results and discussion

Figure 2 shows curves of movement x_2, speed $\dot{x}_2$ and springy forces. Outputs are m_2 = 20 kg; EF = 20000 N; $x_{2(п)}$ = 0,25 m, $\dot{x}_{2(п)}$ = 0,64 m/s, $\dot{x}_{ст}$ = 0,78 m/s. In this case, the velocity difference between $\dot{x}_{2(п)}$ and $\dot{x}_{ст}$ is one of the reasons of oscillation processes.

Curves of velocity and springy forces variations show us perceptible changes of the frequency of natural vibrations of the system during the current phase, which is the result of changing of stiffness. Effect of stiffness is well traced on curves of springy forces variations, according to extreme values of these variations from 215 N at the beginning to 110 N at the end of the process of attenuation, i.e. they decrease 1.95 times. At the same time, stiffness varies 6 times. In that case dynamic component of strain is proportional to $\sqrt{c}$ and therefore is $\sqrt{6} \approx 2{,}45$. This comparison suggests that decrease of stiffness leads to decreasing of springy forces. We can specify such dependence of forces when $P_{оп} = 150$ H (Figure 3). For this case $P_{пр\,max} = 316$ N. Dynamic component of strain in both cases are about 165 N. As you can see, dynamic component of strain are independent from the resistance of movement, so one of the possibilities to avoid negative strains in film is increasing of the resistance of movement of driven masses.

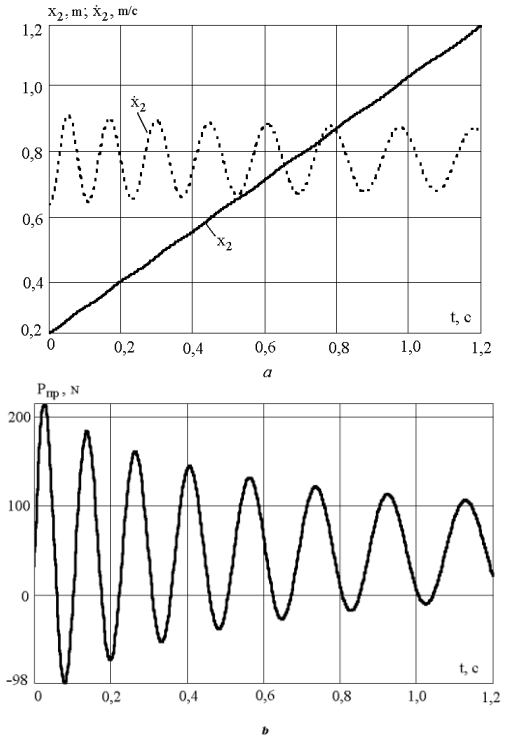

Figure 2. *Charts kinematic (a) and force (b) parameters for $P_{оп}$ = 50 N*

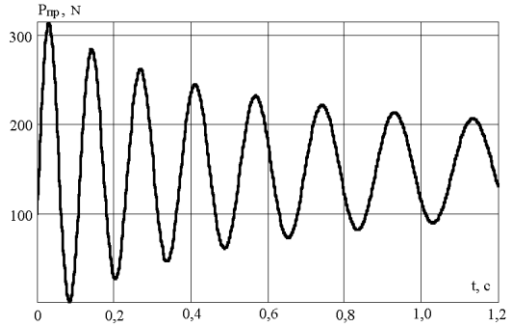

Figure 3. *Charts of force parameters for $P_{оп}$ = 150 N*

IV. Conclusions

As follows from the calculations the speed of the driven mass increases from the initial to the maximum value with the appearance of oscillatory process in reference to predetermined size $\dot{x}_{ст}$. Kinematic parameters of the oscillation process indicate that when other things being equal only value of $\dot{x}_{2(n)}$ matters. Therefore, as the oscillation process attenuates variable stiffness remains the only reason of variable values of $P_{пр}$.

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USE OF COLLAGENASE IN TECHNOLOGY GERODIETETIC PRODUCTS

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Abstract: *The topicality of the work is to justify the choice of low-grade meat raw material as a matrix for tying together calcium ions. A safe, effective and affordable in Ukraine enzyme preparation is chosen from literature sources in order to increase the number of functional groups in the raw material.*

Keywords: meat, gerodietetic, tripe, proteolysis enzyme, collagenase.

I. Introduction

XX century was the age of population growth, XXI can become the age of aging population. According to the UN, it is expected that by 2050 the world population will increase by 2,5 billion people, while the number of people at the age of 60 and older will increase by 1 billion people. The current demographic situation in Ukraine is characterized by persistent tendency - a dynamic increase in the share of people older than working age, which contributes to global aging process of population. Today, 20,7% of the population in Ukraine, that is every fifth citizen - retired due to age, and every fourth, crossed the line of 50 year old.

Today we are talking about reaching potential immortality. The goal of scientists is to look for new tools and methods that will significantly improve the quality of life in order to increase one's performance during their life expectancy, advance the onset time of diseases that accompany old age (osteoporosis, type II diabetes, atherosclerosis, cancer, etc.). It is no accidently, that in the developed by UN Programme project on aging "Scientific research programmes on aging problems in the XXI century", the concept of healthy aging classified as the most priority areas.

Today gerontology has a number of methods and tools that improve health, psychological and physical possibilities of older and elderly age people. The most studied and effective of them is the rational mode of muscle activity and a balanced diet, with the obligatory inclusion in the diet ingredients that have geteroprotective and protective effect. According to domestic and foreign research, through properly organized diet the number of illnesses (diabetes, arthritis - 50%, heart disease - 25%, diseases of eyes - 20%, etc.) can be reduced and significantly reduce the risk of premature aging. Today, there are very few of these substances in our diets, which reduces the protective properties of the organism. For this reason, it is necessary to create specialized food products with specifically declared properties. Therefore, a new look at the potential of biotech food raw materials, grounding of new biotechnological solutions in technology of gerodietic products are particularly important.

The product range of gerodietic products is limited, moreover, the bulk accounts dairy products and baked goods. Therefore, the purpose of this study was to improve the theoretical foundations and design principles of gerodietic products, which are based on the creation of balanced by their micronutritient structure of recipes, adequate needs of seniors, elderly and centenarians.

One of the priority tendency of the concept of the National program "Health 2020: Ukrainian Dimension" (for the period 2012-2020 years) in the sphere of healthy nutrition of Ukraine is to eliminate the deficit of nutrients, including important micronutrients - vitamins and minerals. The problem of solving calcium deficiency both in food and in the human body is of paramount importance. Physiologists have shown that one of the reasons of calcium metabolism violation in the background of its deficit, is a low percentage of absorption of macronutrients, since calcium is one of those nutrients that the body cannot synthesize, and its content in the natural food sources - is limited. Absorption of calcium depends on its relation with other nutrients (phosphorus, vitamin D, fatty acids, etc.). Amount of protein in the diet affects on the assimilability of calcium: with the high-protein diet about 15% of calcium is absorbed, and at low-protein - only 5%.

II. Materials and methods

Therefore, it is necessary to create such food systems, where the maximum amount of calcium will be associated with protein compounds for better assimilation in body. Therefore, as a readily

available source of protein we have chosen by-products of second category, in particular cattle rumen (collagen content 62%). However, to increase the number of functional groups, it was necessary to conduct cattle rumen fermentation.

From the analytical review of the literature due to indexes of collagenases activity (Table 1) collagenase nutritive produced by close joined-stock company "Bioprohres" according to industrial standards 9158-002-11734126-94 (Schelkovo, Moscow region, Russia) was selected as the enzyme.

In the complex research aimed at the solution of the question about possibility and feasibility of using collagenase nutrition in meat production technology, in the first place it is necessary to study the proteolytic activity of the enzyme preparation and the influence on it such process parameters as pH and temperature.

It was founded that the activity of collagenase nutrition in proteolysis of caseinate sodium during fermentation, given the requirements of GOST 20264.2 for neutral proteinase (pH 7,0 temperature 30 ° C and duration of 10 × 60 s) was 288 un / g.

Accepted in the experiment pH range represented interest, as meat pH is 5,6 ... 5,8 and , therefore, the use of collagenase nutrition for enzymatic proteolysis of meat pH environment is slightly shifted to the acid side in comparison with an optimum action indicated in the standard. The results are represented in Figure 1.

Table 1. *Biochemical characterization of enzyme complexes of preparations*

Enzyme preparation (Source)	Activity	
	Proteolityc un/g	Collagenase un/mg
Protosubtylin G10h (Bacillus subtilis)	400	0,07
Protomegateryn G20H (Bacillus megaterium)	119	0,09
Pepsin (Mucous membrane of stomach)	30	0,01
Trypsin (pancreas)	240	0,01
Pancreatin (pancreas)	120	0,13
Collagenase nutritive (Kamchatka crab)	125	0,3
Papain(Papaya)	150	0,15

III. Result and discussing

As can be seen from the data in Figure 1 , collagenase nutrition activity accounts for most per zone pH 5,0 ... 7,5, while shifting the pH to slightly acidic zone the preparation stores 72 ... 90% of the maximum value of its proteolytic activity. It follows that the use of the preparation for cattle rumen fermentation, slightly acidic environmental conditions should not significantly affect its activity.

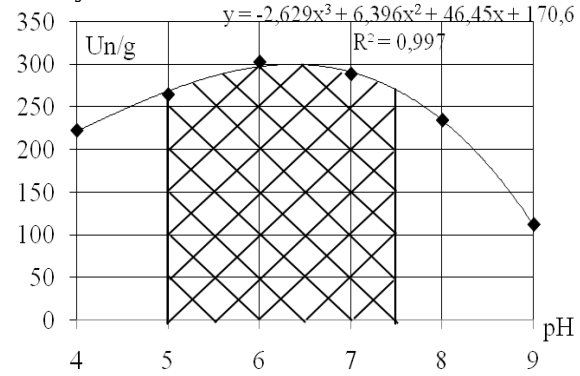

Figure 1. *Dependence of proteolytic activity of collagenase nutrition on the values of pH (t = 30 ° C, τ = 10h60s).*

The dependence of the proteolytic activity of collagenase nutrition on the duration of the process at different values of the ambient temperature measured in the range 0 ... 90 ° C at pH 7,0 during 10 x 60 s. The data presented in Figure 2.

Accepted in the experiment temperature range was suitable for technological production process and, thus, allowed to predict the intensity of enzymatic proteolysis of the protein in a particular technology. Increase of the ambient temperature to 35 ° C leads to an increase in enzyme preparation activity. Further increase in temperature above 45 °C causes partial inactivation of the enzyme preparation; the higher the temperature and longer duration of heat exposure, the more intensively enzyme preparation inactivates.

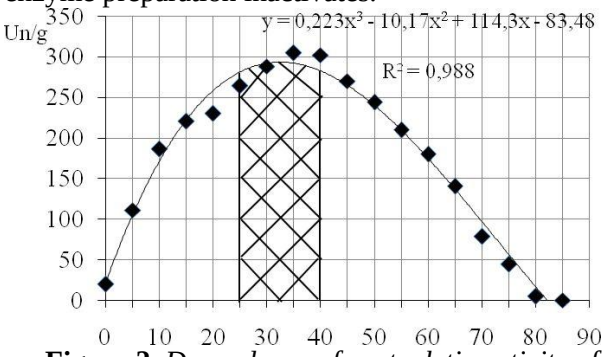

Figure 2. *Dependence of proteolytic activity of collagenase nutrition on temperature values (pH 7,0 τ = 10h60s).*

To determine the rational mode of enzymatic proteolysis a full factorial design method was used, followed by mathematical modeling in problem-oriented package MathCad. As a parameter of optimization amino nitrogen content in the hydrolyzate was selected. Within the two-

factor model experiment, the content of amino nitrogen in the rumen of cattle hydrolyzate according to the temperature and duration of enzymatic proteolysis was calculated by equation:

$$S=-1690,3+10,6\cdot\tau+55,6\cdot t-4,4\cdot10^{2}\cdot\tau-9,19\cdot10^{2}\cdot t-4,9\cdot10^{3}\cdot t$$

where S - content of water-soluble hydrolysis products, mg/g protein; τ - duration of enzymatic proteolysis, s; t - enzymatic proteolysis temperature, ° C.

In the ensuing mathematical modeling the region rational values of the investigated parameters was defined.

It is known that proteolytic enzymes preparations catalyze the cleavage reaction of protein molecules with water. However, the introduction of large amount of water to the rumen of cattle will lead to higher costs in its drying. Justification of the minimum duty water curve that ensures the efficient conduction of proteolysis was carried out by the intensity of accumulation of amino nitrogen in the water-soluble fraction of hydrolysates of cattle rumen at different values of duty water curve. The results are represented in Figure 3.

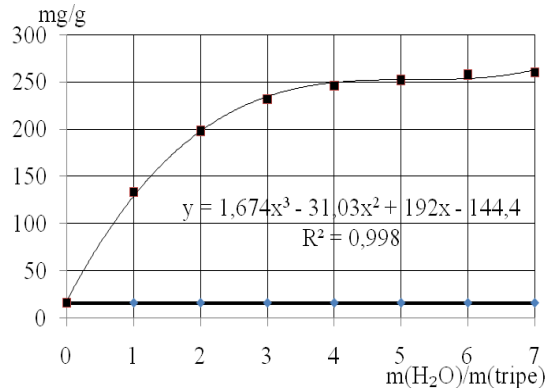

Figure 3. *Content of water-soluble hydrolysis products of cow rumen based on duty water curve: ■ - enzymatic proteolysis; ▲ - endurance in water without fermentation (control).*

According to received experimental data for the effective proteolysis of rumen of cattle sufficient duty water curve is "water: rumen of cattle" - 1:3. Further increase of water content in the environment does not lead to a significant increase in the degree of proteolysis.

To ensure the microbiological safety the mixture is heated to (85 ± 1) ° C and maintained for (10 ± 0,2) s 60. Taking into account the data on thermal inactivation of enzyme composition (Fig. 2), such parameters of heating will provide its full inactivation.

Enzymatic treatment leads to destructive changes of raw materials, increase of number of hydrophilic centers, increase of functional groups as a result of rupture of polypeptide chains, which further will be more accessible for reactions including calcium. However, our goal was not a complete hydrolyzate of protein molecules to amino acids, we tried to achieve only partial hydrolysis to increase the number of free functional groups, including those that are capable of binding calcium.

Processing of cattle rumen was held by 0,05% solution of the enzyme by weight of raw materials (recommendations of Tolstobokov Oleg Mykolayovych) at temperature regimes: 2 ° C (cold chamber), 12 ° C (in meat processing plants in the shops), 20 ° C (room temperature) and 37 ° and 50 ° C (thermostat) for 5 hours.

Proteolysis of protein of collagen containing tissue is observed in all modes, as evidenced by the accumulation of amino nitrogen. The highest rate of proteolysis of proteins is observed during the first time, as shown by angle curves from the second processing time it is reduced. The largest number of amino nitrogen was observed at 37 ° C in each period, minimum - at 2 ° C.

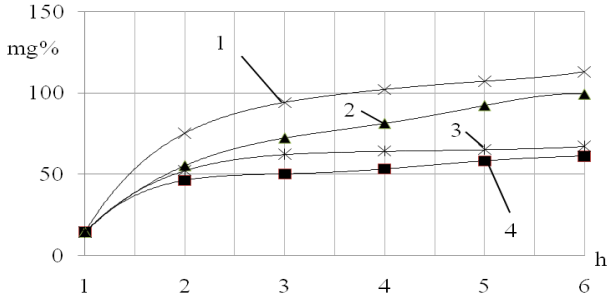

Figure 4. *Diagram of accumulation of aminobitrogen in the processing of the rumen of cattle depending on the ambient temparture. 1. treatment at 2 °C; 2 treatment at 12°C; 3. treatment at 37 °C; 4. treatment at 50 °C.*

So, after 2 hours of fermentation amount of amino nitrogen in samples that were treated at 37 ° C increased by 5,8 times at 12 ° C – 4,5 times, at 2 ° C - 3 times, further the rate of decay of proteins to peptides and amino acids gradually decreased. Thus, the most effective fermentation temperature is 37° C.

In conditions of production the support of 37 ° C entails additional costs for equipment and energy, which is undesirable in the development of new technologies. Also such temperature creates optimal conditions for microbial growth. Therefore, temperature 12 ° C is more suitable,

which is chosen for further studies because it is constantly maintained at a meat processing enterprises in manufacturing plants, but also increased the concentration of enzyme to 0,1%.

It is evidently from the graphs,that the treatment with the double number of enzyme allowed to get after 2 hours such amount of amine oxide, which was achieved at 37 ° C for 4 hours. Therefore, further treatment of collagen containing raw material was conducted by collagenase solution in an amount of 0,1% by weight of raw materials at 12 ° C for 3 hours.

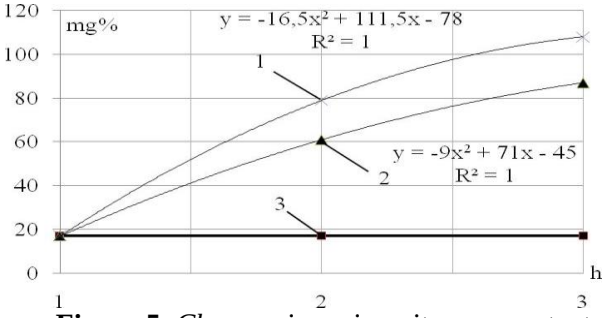

Figure 5. *Changes in amino nitrogen content at different concentrations of enzyme preparation*

Collaterally, the dynamic changes of content in soluble protein in processing by collagenase nutrition solution in an amount of 0,05 and 0.1% by weight of raw material.

Table 2. *Changes in the content of soluble protein by the action of collagenase nutritive*

Duration of fermentation, h	Water-soluble protein,%	
	0.05% by weight of raw	0.1% by weight of raw
1	1,14±0,03	1,72±0,07
2	1,3±0,01	2,04±0,02
3	1,38±0,01	2,17±0,05
4	1,4±0,07	2,26±0,04
5	1,405±0,09	2,3±0,02
6	1,41±0,05	2,32±0,03

Water-soluble protein of native form scar cattle equal 0,6%. The results are represented in Table 2.

The analysis of the received data showed that there is a direct correlation with the amino nitrogen, that is processes of accumulation of soluble fractions and accumulation of amino nitrogen are going in parallels. As expected, during the processing by 0,1% solution of enzyme the amount of soluble protein is higher, moreover, the greatest increase of soluble protein is observed within the first hour. Since the second hour of fermentation, the rate of formation of soluble protein decreases and slows down at fourth hour of fermentation.

IV. Conclusion.

1. Analysis of experimental data and also their mathematical treatment, allowed to justify the use of enzyme preparation - nutritive collagenase to increase functional groups in the by-products of II category (rumen of cattle).

2. It is shown that the effective concentration of nutritive collagenase during proteolysis of the cattle rumen is – 0,1% by weight of raw material.

3. It is founded that the maximum proteolytic activity of enzyme preparation - nutritive collagenase at pH - 5,0-7,5; duty water curve - 1:2; temperature - 25-40 ° C, proteolysis duration - 3 hours.

4. It is determined that for cattle rumen fermentation ,aiming at technology efficiency , temperature 12 ° C can be used, which is kept in production facilities meat processing enterprises, but the duration of proteolysis increases by 1:00.

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IMPROVING THE PERFORMANCE OF ENTERPRISES IN THE REGION THROUGH AN INTEGRATED RECYCLING

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Abstract. *The major direction of improving efficiency and the development of processing industry is the creation of waste - free technologies to produce competitive products. Non-waste production involve improving those processes that provide the best possible comprehensive processing of raw materials. This allows, on the one hand, the most efficient use of natural resources, fully recycle waste in a commercial product, but on the other - to reduce the amount of waste and thereby reduce their negative impact on ecological systems.*

Keywords: secondary raw materials, animal feed, vegetable raw materials.

The problem of the use of secondary raw materials produced in the processing of agricultural raw materials, is now being given sufficient attention in the world, developed science-based methods for its processing and use on the basis of physical, chemical and biological methods to extract and concentration of the components. Waste vegetable and animal raw materials play an important role in food, environmental and energy problems. They should be regarded as optional, and in some cases, alternative sources of valuable components of natural origin. The main sec-tors associated with obtaining waste are: agriculture, food and processing industries, catering. Most of the waste is moved without the appropriate treatment (disinfection) for general landfill or sent direct pipeline to sewers, which leads to disruption of the ecological balance.

Given the properties of the chemical composition and safety for human health vegetable waste can be divided into the categories presented in Figure 1.

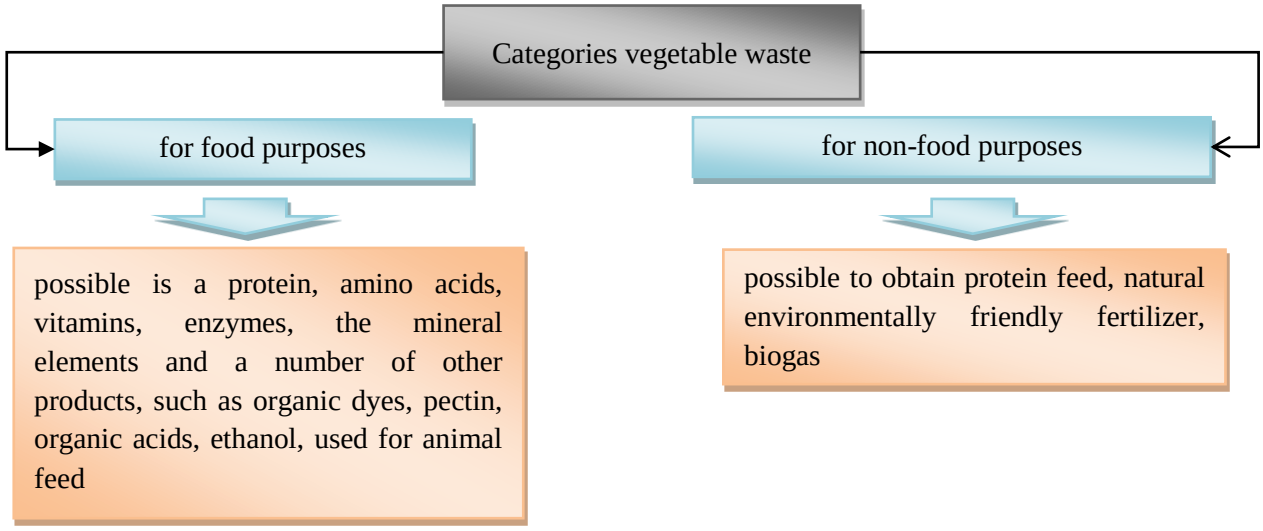

Fig. 1. *Categories of plant waste and the possibility of their further processing*

During the processing of fruits and vegetables according to the type of raw material used and products obtained technology, waste can be up to 50 % of the feedstock. They are formed during cleaning, cutting, wiping, compression, and other operations. So the first way of rational use of raw materials - waste reduction. However, the waste cannot be completely cut. During the processing of fruits and vegetables in the form of unavoidable waste skins, seeds, seed socket seed husks, and other species that contain valuable nutrients. The most efficient way of using such raw materials - is it relevant in the technological transformation of products, technology of production which guarantees microbiologically safe products.

In the canning industry, the raw material used for no more than 90 %, respectively, annually produced thousands of tons of waste of valuable secondary raw materials, which can be a full feed, whose use in livestock will significantly increase the number of animals and their productivity.

Wastes generated during technological processing of fruits and vegetables, can be arbitrarily divided into the following groups:

- Early, with mechanical damage, do not correspond to the shape, size and standard requirements of fruits and vegetables without microbiological damages;
- Cleaning, bagasse, pulp and certain anatomical parts of plants produced in the course of processing, seeds, seeds, seed chambers, stalk, stumps, etc.;
- Liquid wastes generated during grinding, rubbing, extraction, blanching and pre- cooking of vegetable materials;
- Fruits and vegetables, processed products that have excessive amounts of hazardous and harmful substances to human health ;
- Fruits, vegetables and derived products affected by microorganisms.

The last two groups of waste for processing into food needs are not suitable, they can be used for fertilizer, feed protein, biogas. Thus, for each waste stream requires an individual approach, based on their chemical composition, physical state and security for people and the environment.

Note that in the Voronezh region is well developed animal husbandry, which is an important branch of agriculture. In a market economy in this sector there was not an easy situation, reflected in the reduction of livestock, the collapse of many businesses, the decrease of production, material and technical equipment of the deterioration of the industry.

The main condition for an increase in livestock production is to provide a variety of animal feed. With the high cost of the basic food for reducing the cost of production, it is necessary to use alternative raw materials, such as waste products of the canning industry in the production of apple juice and jam in the form of apple pomace. Feeding animals like pet will quickly and at no additional cost to increase animal productivity and improve product quality. The main difficulty in this is the need to change the direction of development of the processing industry, which will require appropriate investment and above all to establish the general information on the benefits of waste.

Apple juice processing on in our country has a significant share in the total number of processed apples. This produces pomace, which usually is 35 - 40% by weight of recycled apples. Nutritional value of one kilogram of apple pomace equals 0,24 feed units and 13 g of digestible protein. In many enterprises, natural juices are produced by pressing remain pomace. Disposal of waste in these enterprises is very expensive. Pomace their acidity when plowing the ground disrupt the structure of the soil, therefore it is necessary to deoxidize later. With the introduction of recycling husks in enterprises will be put in the process of zero waste and the waste will not pollute the soil. In addition, the use of apple pomace as an alternative to the production of feed mixtures, saving concentrated feed and feed production to solve the problem with the addition of dried apple pomace.

Currently, most of the pomace are not used, although the volumes of apple processing in the production of apple juice can get more than 8 tons of dry bagasse per year. Russian enterprises have recently harvested at least 700-750 thousand tons of apples and apple processing volume increased by almost 35 %, indicating that, first of all, the growth of consumption of apple juice in the country. Note that the Voronezh region is a rich source of raw materials and the region ranks 6th in Russia in terms of gross collection of fruits and berries (Figure 2).

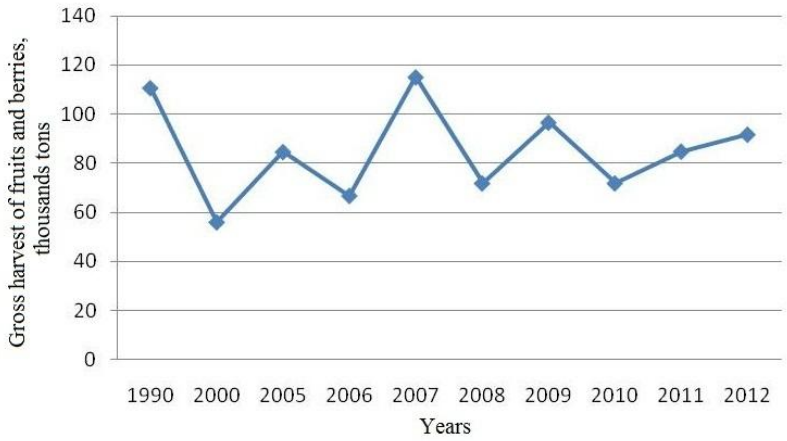

Figure 2. *Production of fruits and berries for 1990-2012, thousands Rub.*

You can select multiple areas of processing this type of secondary raw materials, which are illustrated in Figure 3.

Raw bagasse during storage and transport fermented quickly and lose their nutritional value. An excess of the feed means are dried, and processed into flour instead of pigs given concentrates.

Flour from apple pomace is effective in prevention of anemia of suckling piglets. Feeding pigs in the first 4-5 weeks of life, starting with a 3- 5 -day-old, approximately 500 g of flour from malic marc fully covers their body with iron prevents the onset of the disease. The use of these feeds in the diet of sows during the week before farrowing and months after the 0.5 kg per head per day can prevent postpartum constipation, anemia, queens and reduce the incidence of gastroenteritis in piglets.

In determining the effectiveness of implementation of development, it was necessary to determine the economic feasibility of replacing expensive raw materials, components, and alternate, respectively, to study in piglets for fattening some of the indicators : nutritious food, its exchange energy, as well as growth, development, behavior of fattening pigs using apple pomace.

Based on the studies found that for the same live weight of animals in the experimental groups beginning of the experiment, the maximum mass to the end of the experiment gilts were treated in 20% of the diet dry apple pomace – 115,3 kg, which exceeded 10% of the treated pigs. apple pomace at 3,8 kg, while the control group of pigs fed in the diet dry pomace 15,1 kg. In the same group there is the largest number of fast-growing pigs - 37 %, and the minimum number of animals tugorastuschih - 32%.

Replacement of complete feed dry ap-ple pomace in an amount up to 20% of the nutritious diet can accelerate the growth, the development of the animals, as well as the best way affects the quality and composition of the meat.

During the testing of secondary raw materials for fattening piglets found that the best fattening and slaughter qualities of different animals, in which 20% of the diet nutritionally Complete feed was replaced with dry apple pomace, which was expressed relative to a control : in the reliable reduction of the period of fattening of 15 days of average daily increase a gain of 132 g, reducing costs by 0,9 feed fodder units. or 25,4 %, increase in carcass yield of 4,1 %.

Cost-effectiveness has shown, that the production of pig us when replacing complete feed dry apple pomace cost-effective. The use of dry apple pomace for replacement of feed at 20% on nutrition can improve profitability by an average of 13,1%.

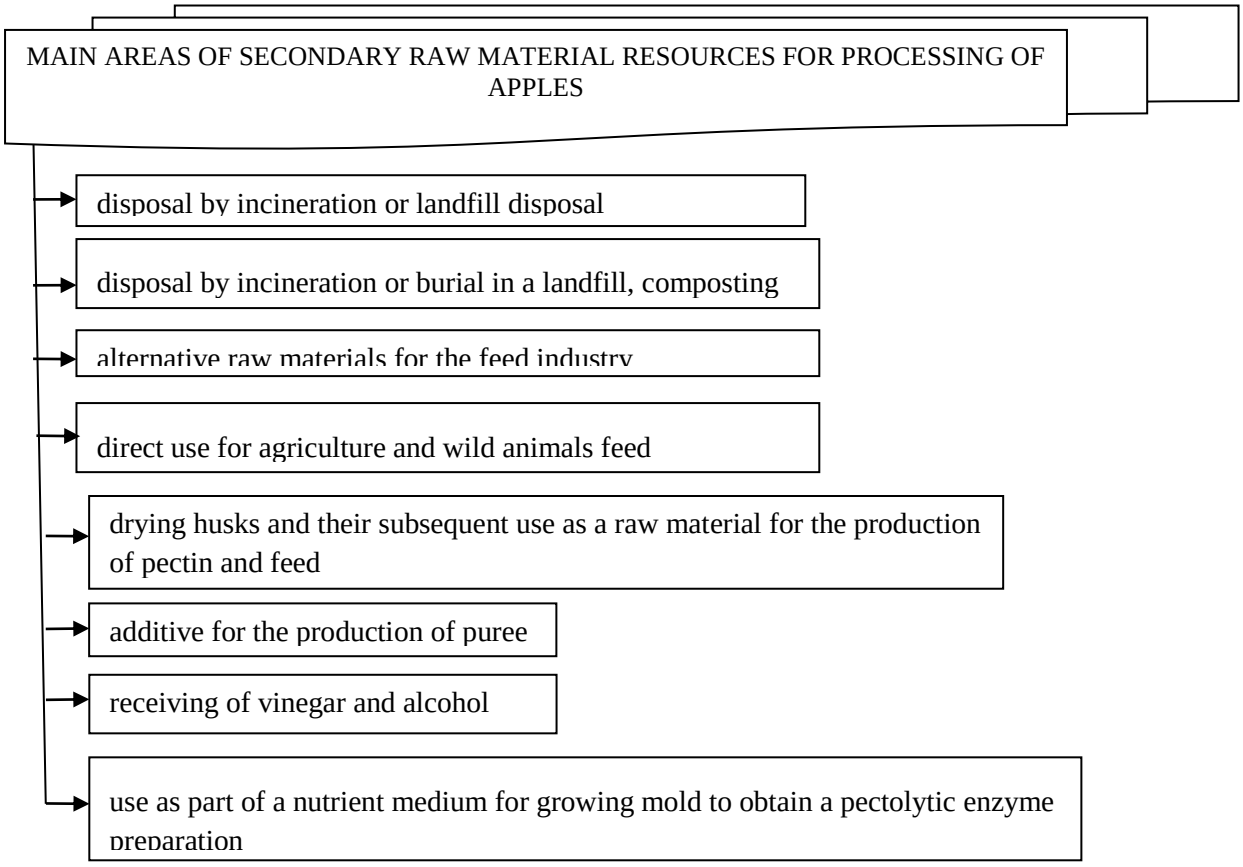

Figure 3. *Main directions of use of secondary raw materials in the processing of apples*

Conclusions

In conclusion, it is worth noting that the main feature of alternative technologies is integrated feed production, which is the ability to comprehensively address current problems of agricultural enterprises, namely, to provide high-quality forage management ; solve environmental issues on waste management, provide energy and heat supply enterprises. The introduction of the proposed measures on complex processing of secondary raw materials will increase the competitiveness and efficiency of enterprises in the region.

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STEROL COMPOSITION OF MELON SEED OILS (*CUCUMIS MELO*)

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Abstract. *The composition of sterols and sterol esters isolated from the seeds of three melon varieties introduced in Bulgaria – Medena rosa, Deserten 5 and Hybrid 1 was investigated. The content of oil in the seeds was 41,6% to 44,5%. Sterols in the glyceride oils were found to be 0,60% including 0,45%, 0,49%, 0,48% free sterols, respectively, and 0,14%, 0,08%, 0,10% esterified sterols, respectively. β-Sitosterol in two melon varieties - Deserten 5 and Hybrid 1 predominated in both free and esterified sterol fractions, being respectively 64,7–70,8% and 55,7–58,4%, followed by Δ^5-avenasterol (19,7–22,9% and 35,8–38,8%, respectively). Δ^5–avenasterol predominated in esterified sterols of the variety Medena rosa (48,4%), followed by β-sitosterol (44,7%). The quantity of Δ^5–avenasterol in free sterols is smaller than the quantity of β-sitosterol in variety Medena rosa – 38,1% and 52,9% respectively. The content of cholesterol in sterol esters (0,5–1,1%) was several times higher than in the fraction of free sterols (0,2–0,3 %).*

Key words: *melon seed oil, free sterols, esterified sterols*

I. Introduction

Melon (*Cucumis melo*) belongs to the *Cucurbitaceae* family. It grows in tropical regions but also in Bulgaria. The fruits have pleasant flavor and taste, and the seeds are generally treated as waste; however, medicinal effects have been reported about seeds [3, 4, 11]. Melon seeds are valuable source of oil and proteins. The oil content in the seeds is 23–55% and the protein quantity is 23–35% [10, 11]. Melon seed kernels are major soup ingredients and they are used as a thickener and flavor component of soups. Melons seeds contribute substantially towards obtaining a balanced diet [2, 5]. The seeds also contain phytosterols which contribute the decreasing of cholesterol. The oil is used as cooking oil in some countries in Africa and the Middle East [10] and for human consumption because they contain high amount of polyunsaturated fatty acids. Moreover melon glycerid oil contains biological active components as sterols and tocopherols which are natural antioxidants and synergists against the lipid auto-oxidation. Sterol composition indicates the quality of the oil. The literature data about sterol composition of melon seed oil of Bulgarian origin is very scarce. There is no data about the content and ratio of free sterols and esterified sterols.

The aim of the present work was to investigate the content and the individual composition of the sterol fraction in three varieties melon seeds oil grown in Southern Bulgaria.

II. Materials and methods

Melon seeds (*Medena rosa*, *Deserten 5* and *Hybrid 1*) were grew in region of Plovdiv, Bulgaria, crop 2012. The investigation was carried with air-dried seeds in technical maturity.

Isolation of glyceride oil and determination of oil content. The seeds (50g sample) were air-dried and ground to powder and the oil was extracted with n-hexane in *Soxhlet* apparatus for 8 h. The solvent was partly removed in rotary vacuum evaporator, the residue was transferred in pre-weight glass vessels and the rest of the solvent was removed under stream of nitrogen to a constant weight to determine the oil content [8].

Determination of sterol composition. The total oil sample (sample size of 100 mg, precisely measured) was applied on a 20 cm x 20 cm glass plate covered with 1 mm thick silica gel 60 G layer (Merck, Darmstadt, Germany) and developed with diethyl ether: hexane (1:1 v/v). Free (Rf =0,4) and esterified (Rf =0,8) sterols were detected under UV light by spraying the edges of the plate with 2′,7′-dichlorofluorescein and then they were scraped, transferred to small glass columns and eluted with diethyl ether [9]. The solvent was evaporated under a stream of nitrogen, the respective residues were weighed in small glass containers to a constant weight. Free sterols were subjected to gas chromatography (GC) without derivatization. Sterol esters were hydrolyzed with ethanolic KOH [9] and then sterols were extracted with light petroleum ether and purified by TLC under the conditions given above prior to the GC analysis. Sterol composition was determined on HP 5890 gas chromatograph

(Hewlett Packard GmbH, Austria) equipped with 25 m x 0,25 mm DB 5 capillary column (Agilent Technologies, Santa Clara CA, USA) and flame ionization detector (FID). Temperature gradient was: 90°C (held for 2 min) to 290°C at 15°C/min then to 310°C at 4°C/min and held at this temperature for 10 min; the injector temperature was 300°C and the detector temperature was 320°C. Hydrogen was the carrier gas at a flow rate of 0,8 ml/min; split 100:1. Identification was performed by comparison of the retention times with those of a standard mixture of sterols [7]. Individual quantitative composition was determined as ratio of peak areas.

III. Results and discussion

The data about the oil in the seeds and sterol content in the oil of the three species of melon are shown in Table 1.

As can be seen the seeds are rich in glyceride oil (41,6–44,5%). The total sterol content was 0,60%. These values were similar to the data for sterol content of melon seeds reported in previous publications [6]. The major part of the sterols (75–82%) was presented in free form.

The qualitative and quantitative composition of the free and esterified sterols was shown in Figure 1 and Figure 2.

The qualitative profile of free and esterified sterols was identical in the all investigated varieties, but the quantitative composition was found to be different. The main components in both sterol fractions were β-sitosterol, Δ^5–avenasterol, campesterol and stigmasterol.

β-Sitosterol (52,9–70,8%) and Δ^5–avenasterol (19,7 – 38,1%) predominated in the fraction of free sterols. Stigmasterol and Δ^7–avenasterol were identified, respectively 3,1–4,6% and 0,5–11,1%. Campesterol and cholesterol were established in negligible amounts - about 0,3–0,7% and 0,2–0,3% respectively.

In variety *Medena rosa* the content of β–sitosterol was lower (52,9%), but the content of Δ^5–avenasterol was higher (38,1%) than in the other two species. In *Deserten 5* and *Hybrid 1* species the quantity of β–sitosterol was higher (70,8 and 64,7%) at the expense of the lower content of Δ^5–avenasterol. Δ^7–Avenasterol was in higher quantity in *Hybrid 1* (11,1%) than in *Medena rosa* and *Deserten 5* (4,7 and 0,5%, respectively).

Table 1. *Content of oil and sterol content of three species of melon seeds**

Melon species	Oil content, %	Total sterols, %	Free sterols, %	Esterified sterols, %
Medena rosa	41,6±0,2	0,60±0,05	0,45±0,05	0,14±0,01
Deserten 5	44,5±0,1	0,60±0,03	0,49±0,03	0,08±0,02
Hybrid 1	41,6±0,1	0,60±0,05	0,48±0,02	0,10±0,01

*Means of triplicate analysis ± SD

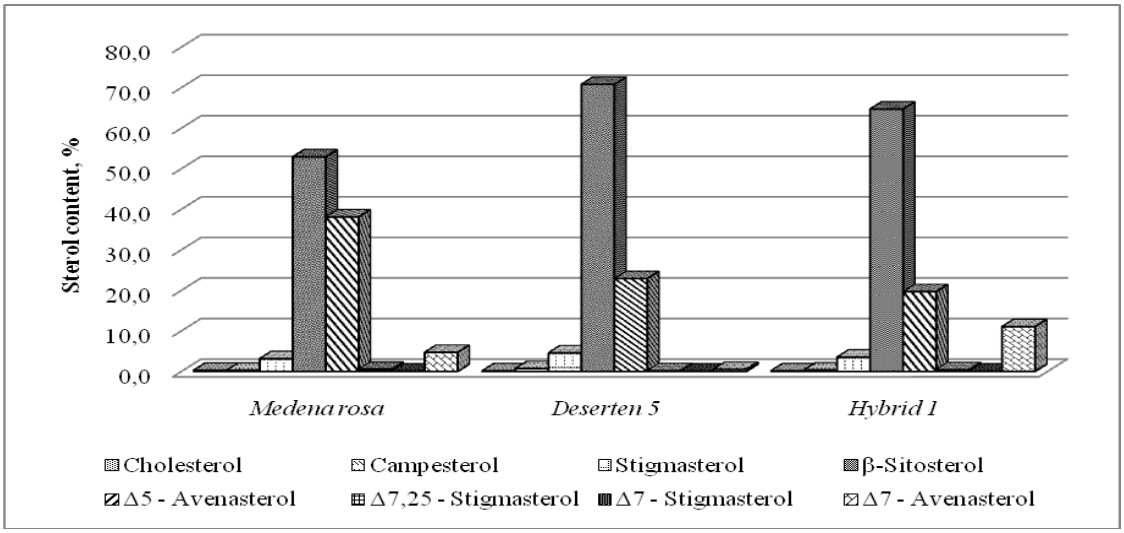

Figure 1. *Composition of free sterols in three melon seed oils species* (*Medena rosa*, *Deserten* 5 and *Hybrid* 1)

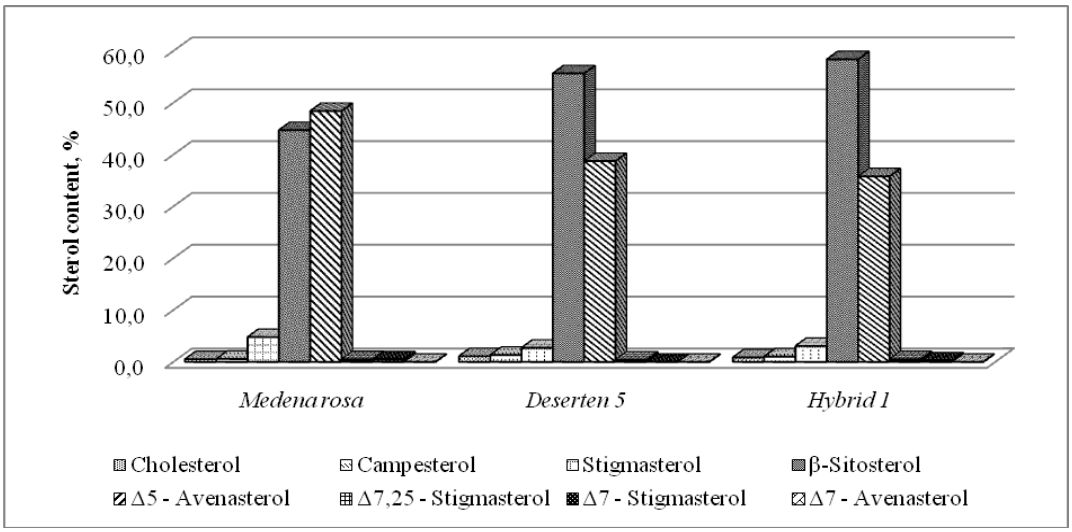

Figure 2. *Composition of esterified sterols in three melon seed oils species* (*Medena rosa*, *Deserten* 5 and *Hybrid* 1)

β-Sitosterol predominated also in the fraction of esterified sterols in two species of melon (*Deserten* 5 and *Hybrid* 1) and was 55,7 – 58,4%, followed by Δ^5–avenasterol (35,8 – 38,8%). Δ^5–Avenasterol predominated in the oil from species *Medena rosa* (48,4%), followed by β–sitosterol (44,7%). The content of β–sitosterol in *Medena rosa* was lower than in *Deserten 5* and *Hybrid 1* at the expense of the higher content of Δ^5–avenasterol. The quantity of stigmasterol and campesterol was 2,7–4,8% and 0,6–1,3%, respectively. The cholesterol content in esterified sterols varied from 0,5 to 1,1%. Δ^7–Avenasterol was observed in trace only.

The quantity of β–sitosterol in the fraction of free sterols was higher than in esterified sterols while the amount of Δ^5–avenasterol in the fraction of the esterified sterols was higher than in free sterols. The quantity of stigmasterol is the same in free and esterified sterols. A marked differences was established in the cholesterol content between free and esterified sterols. The content of cholesterol in sterol esters (0,5–1,1%) was several times higher than in the fraction of free sterols (0,2–0,3 %). These differences can be put down to the different phases of the biosynthesis and accumulation of those compounds. In the first stage cholesterol was synthesized and then it was used as precursor for synthesis of sterol esters. Free sterols were synthesized, then sterol esters are accumulated and the content of cholesterol was exhausted.

These results were in good agreement with the finding of *Abdalbasit et al.* и *Albishri et al.* [1, 3]. In comparison with other vegetable oils higher quantities of unsaturated sterol derivatives as stigmasterol, Δ^7-stigmasterol, Δ^5–avenasterol Δ^7–avenasterol were established in all varieties of melon.

IV. Conclusion

The seeds of three investigated varieties of melon were rich in glyceride oil. The sterol composition of melon seed oil is similar to this of other melon species. More unsaturated sterol derivatives predominated in free sterol fraction.

The information about oil content of the seeds and sterol composition of the oil can be used for examination of food value of melon seed oil as a valuable source of biological active compounds.

Acknowledgements

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OPTIMIZATION OF TRANSPORTATION OF BULK SOLIDS FOOD PRODUCTS IN THE LINEAR WEIGHTFEEDER OF PACKING MACHINE

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Abstract. *In this article considers Research results of work linear weightfeeder of packing machine subject to "rough" and "exact" dosing modes. For optimization of transportation of bulk solids food products in this weightfeeder was offered to use such assistive devices, as limiting guide. This guide provide the following conditions:vertical falling of product's solids into weigher capacity; falling of product's solids to a geometrical center of weigher capacity subject to "rough" and " exact" dosing modes.The mathematical analysis and graphical modeling position guide enabled to decide on its type and operation mode.*

Keywords: bulk solids food products, linear weightfeeder, packing machine, limiting guide, weigher capacity, vibratory feeder.

I. Introduction

At the present stage of development of the packaging industry, packaging machines for bulk solids food products is taking on employment use. This is due to increasing range of products and increase in the production of such products, its various structural and mechanical properties, the advent of new types of packaging materials and packaging [1].

Machines with using linear weightfeeder are dominating today in the domestic market of packaging mashines for bulk solids food product.

Dosage are performed in several stages in this devices:

- discharging of products from hopper through the discharging passage;
- transportation product with a given intensity in the direction of weigher capacity(subject to "rough" and " exact" dosing modes) in feeder's conveyor;
- falling products under the influence gravity from feeder's supporting surface into weigher capacity;
- accumulation and weighing products in the weight capacity ;
- unload the weigher capacity.

At each stage of dosing is essential to know the factors and their interaction, affecting the accuracy of dosing, which is the main criterion of effectiveness device as well as packing machine generally.

It is well known that for a weightfeeder between productivity dosing accuracy has definite relationship [4-8].

If you are using this steps to improve productivity of weightfeeder, then dosing accuracy is reducing:

- increasing the product's speed discharge through hopper’s discharging passage;
-increasing layer thickness of products on feeder’s conveyor;
- increasing the feeding conveyor speed;
-increasing the relative duration of "rough" dosing.

II. Materials and Methods

Also at increasing transportation velocity products by feeder (subject to "rough" and "exact" dosing modes) deviation of relative flight trajectory of product's solids is increasing the to the axis of symmetry of the position weigher capacity. This deviation of trajectory affects the accuracy of was offered to use such assistive devices, as limiting guideweighing system, so in order to ensure stable transportation of bulk solids products. This guide should provide the following conditions:

- vertical falling of product's solids into weigher capacity;
- falling of product's solids to a geometrical center of weigher capacity subject to "rough" and "exact" dosing modes.

Linear weightfeeder with vibratory feeder are the most common in the packing machines (Fig. 1). Consider transportation bulk solids food products to determine geometry of the limiting guide and her position subject to "rough" and "exact" dosing modes for such linear weightfeeder.

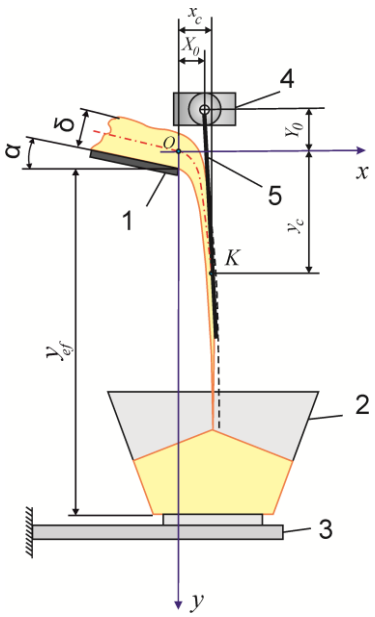

Figure 1. *Loading diagram of dosing bulk solids food products to the weigher capacity in the linear weightfeeder with vibratory feeder :*
1 - vibratory feeder, 2 - weigher capacity, 3 - weighing system, 4 - pivot actuator, 5 - limiting guide

Such following assumption was to make to simplify the mathematical model of the impact of product's solids to guide:

- the impact of product's solids to limiting guide can to describe as an elastic-plastic impact;
- bulk solids product is disconnecting, fine factional;
- solids size product neglect and consider its movement as a movement of material particle;
- material particle movement along the trajectory of the fall solids from average thickness of products on feeder's conveyor.

To determine the required location, type and configuration guide needs to do: research the movement trajectory of material particle, mathematical modeling of elastic-plastic impact of material particle to limiting guide and choice of actuator.

For mathematical modeling of movement trajectory of material particle needs to specified coordinate system.

The origin of coordinates is at the point of falling bulk solids products from feeder. Axes Ox and Oy placed respectively horizontally and vertically. Then the coordinates (x (t), y (t)) and the projection of the velocity of falling (x '(t), y' (t)) of the material particle of vibratory feeder relative to axes Ox and Oy can be described by the following formula (Fig. 2):

$$\begin{cases} x(t) = V_0 \cdot t \cdot \cos(\alpha); & (1) \\ y(t) = V_0 \cdot t \cdot \sin(\alpha) + g \cdot t^2; & (2) \end{cases}$$

and

$$\begin{cases} x'(t) = V_0 \cdot \cos(\alpha); & (3) \\ y'(t) = V_0 \cdot \sin(\alpha) + 2 \cdot g \cdot t, & (4) \end{cases}$$

where $y(t) = 0 \ldots y_{max}$ – the current value of the height of the falling material particle;

$y_{max} = 0{,}5\ \delta / \cos(\alpha) + y_{ef}$ – maximal height of the falling material particle [2]; δ – thickness of products on vibratory feeder; α – angle of inclination of vibrating feeder to the horizontal axis Ox; V_0 – velocity of transportation products by feeder; t – the current value of fall time of material particle.

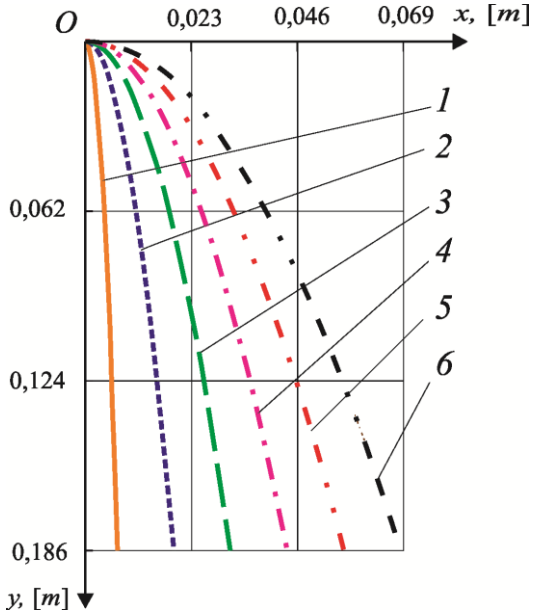

Figure 2. *Trajectory of falling material particle of vibratory feeder that operates at different velocities:*
1. $V_0 = 0{,}05$ [m /s]; 2. $V_0 = 0{,}14$ [m /s];
3. $V_0 = 0{,}23$ [m /s]; 4. $V_0 = 0{,}32$ [m /s];
5. $V_0 = 0{,}41$ [m /s]; 6. $V_0 = 0{,}50$ [m /s]

The current value of fall time of material particle into weigher capacity:

$$t = 0{,}5\ g \cdot \{[(V_0 \cdot \sin(\alpha))^2 + 4 \cdot g \cdot y)]^{0,5} - \ldots \ldots - V_0 \cdot \sin(\alpha)\}, \quad (5)$$

and the formula of the curve that describes the trajectory of the falling material particle can be derived from formula (1, 5):

$$x(t) = 0{,}5\ g \cdot V_0 \cdot \cos(\alpha) \cdot \{[(V_0 \cdot \sin(\alpha))^2 + \ldots \ldots + 4 \cdot g \cdot y)]^{0,5} - V_0 \cdot \sin(\alpha)\}. \quad (6)$$

Velocity of falling material particle:

$$V_b(t) = \{[x'(t)]^2 + [y'(t)]^2\}^{0,5} = \{V_0^2 + \ldots + 4 \cdot g \cdot t \cdot (V_0 \cdot \sin(\alpha) + g \cdot t)\}^{0,5}. \quad (7)$$

To determine the position of the guide need to do mathematical modeling of elastic-plastic impact of material particle to limiting guide under next initial conditions.

1. The impact of material particle to limiting guide can to describe as an elastic-plastic impact. From [3] coefficient of restitution for elastic-plastic impacts is given as:

$$k_i = tg(\varphi_b(t)) / tg(\varphi_a(t)). \quad (8)$$

$\varphi_b(t)$ – angle of reflection before impact;

$\varphi_a(t)$ – angle of reflection after impact.

2. A geometrical center of weigher capacity located at the point of falling product's solids, which was transported by vibratory feeder subject to "exact" dosing modes:

$$x_c = 0{,}5g \cdot V_{0min} \cdot \cos(\alpha) \cdot \{[(V_{0min} \cdot \sin(\alpha))^2 + \ldots + 4 \cdot g \cdot y)]^{0,5} - V_{0min} \cdot \sin(\alpha)\}; \quad (9)$$

where V_{0min} - minimal transportation velocity of product's solids by vibratory feeder subject to "exact" dosing modes.

3. After impact, the material particle should fall vertically into the geometric center of the weigher capacity subject to "rough" and "exact" dosing modes:

$$\begin{cases} x_a = x_c, & (10) \\ y_a = \mathrm{tg}(\alpha) \cdot x_a + g \cdot (x_a)^2 / (V_0 \cdot \cos(\alpha)), & (11) \end{cases}$$

Research of geometry impact of material particle to limiting guide was maked, provided the origin of coordinates of the new coordinate system (Fig. 3) coincide with the point of impact of bulk solids products to limiting guide. Axes Ox' and Oy' placed respectively horizontally and vertically.

Since the geometry of the guide is unknown, we can provide its only additional coordinate axes On and $O\tau$. They coincide with the normal and tangent to the guide at the point of impact of bulk solids products to limiting guide.

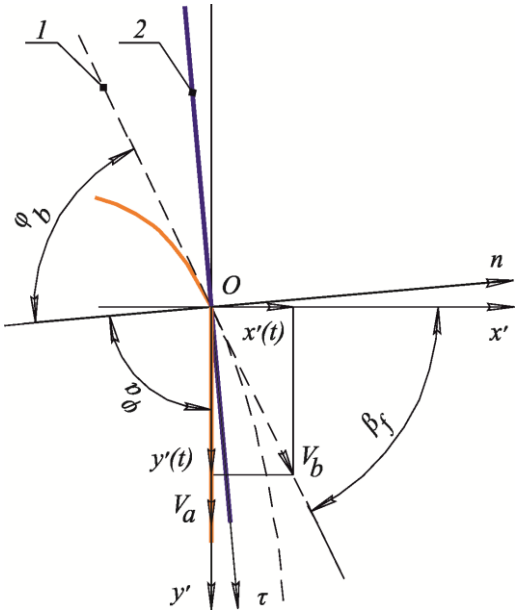

Figure 3. *Loading diagram of elastic-plastic impact of material particle to limiting guide*

According to loading diagram (Fig. 3), falling angle of material particle to the axes Ox':

$$\beta_f(t) = \arccos\{x'(t) / V_f(t)\}.$$

Then taking into account (3,7) the formula for determining falling angle of material particle is:

$$\beta_f(t) = \arccos\{V_0 \cdot \cos(\alpha) / [(V_0^2 + \ldots + 4 \cdot g \cdot t \cdot (V_0 \cdot \sin(\alpha) + g \cdot t)]^{0,5}\}. \quad (12)$$

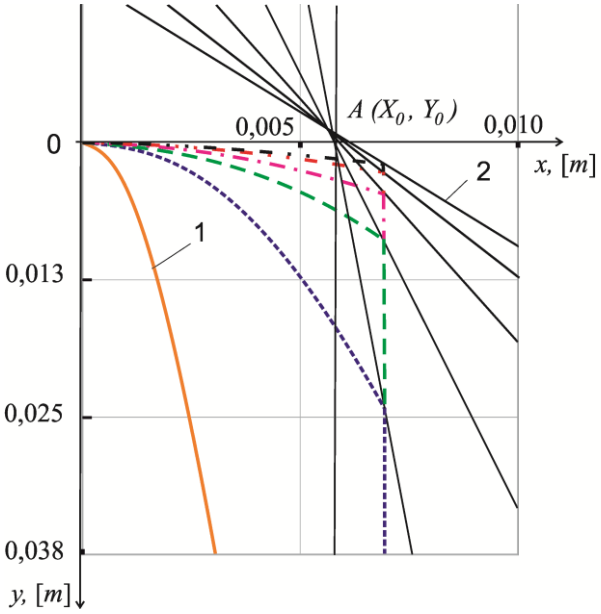

Figure 4. *Graphs tangent to the guide at different velocities of transportation bulk solids products in vibratory feeders:*
1 - trajectory of material particle;
2 - the tangent to limiting guide at the point of impact;
V_0 = 0,05 [m /s];
V_0 = 0,14 [m /s];
V_0 = 0,23 [m /s];
V_0 = 0,32 [m /s];
V_0 = 0,41 [m /s];
V_0 = 0,50 [m /s].

Falling angle of material particle to the axes On:

$$\varphi_b(t) = \beta_f(t) + \pi / 2 - \varphi_a(t), \quad (13)$$

III. Results and discussion

The graph (Fig. 4) is visible: the tangent to the guide at the impact point also is its traces; deviations between the points of intersection of tangents are insignificant.

Therefore, can assume that the tangents intersect at some point $A(X_0, Y_0)$. And the guide can be represented as a swivel shutter.

Location swivel of guide determined from formula (16, 17), which describe the desired position of the guide subject to such condition of transportation material particles in vibratory feeder

as: minimal velocity V_{0min} ("exact" dosing modes) and maximal velocity V_{0max} ("rough" dosing modes):

$$\begin{cases} Y_0 = y_{c(min)} + tg(\varphi_{a(min)}) \cdot (X_0 - x_c); & (16) \\ Y_0 = y_{c\,(max)} + tg(\varphi_{a(max)}) \cdot (X_0 - x_c), & (17) \end{cases}$$

where $y_{c\,(min)}$; $y_{c\,(max)}$ – coordinates of impact point of material particle to limiting guide subject to minimal and maximal velocity of transportation material particles in vibratory feeder; $\varphi_{b(min)}$; $\varphi_{b(max)}$ – angle of reflection before impact subject to minimal $V_{0\min}$ and maximal $V_{0\max}$ velocity of transportation material particles in vibratory feeder.

By solving the system of equations (16, 17) can get swivel coordinates:

$$\begin{cases} X_0 = x_c + [\, y_{c\,(min)} - y_{c\,(max)} \,] / [tg(\varphi_{a(max)}) - \ldots \\ \quad \ldots - tg(\varphi_{a(min)})] \,; & (18) \\ Y_0 = [\, y_{c\,(min)} \cdot tg(\varphi_{a(max)}) - y_{c\,(max)} \times \ldots \\ \quad \ldots \times tg(\varphi_{a(min)})] / [tg(\varphi_{a(max)}) - tg(\varphi_{a(min)})] \,. & (19) \end{cases}$$

IV. Conclusion

The mathematical analysis and graphical modeling position guide enabled to decide on its type and operation mode: guide made as a swivel shutter; guide execute oscillatory motion, To drive the guide recommended rotary actuators.

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SCIENTIFIC SUBSTANTIATION OF COMBINED GRIPPING DEVICES PARAMETERS IN EQUIPMENT FOR GROUP PACKAGING

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Abstract. *The article considers the possibility of using combined gripping devices for execution of technological operations in equipment for group packaging. A mathematical model developed for determining basic kinematic and dynamic parameters of such structures based on physic - mechanical properties of packaging units, which allows limiting the effect of holding effort and save marketable view of packages. It was conducted a comparative analysis of holding efforts by vacuum, mechanical and combined gripping devices. The results can be used for developing new designs of combined gripping devices in equipment for group packaging.*

Keywords: group package, holding efforts, combined gripping device, group packing equipment.

I. Introduction

Present of packaging industry characterized by development and use of a large range of packages, which have different shapes, sizes, weight, physical and mechanical properties of the materials from which they made, original supporting consumer packaging items. For a convenient transportation of packages from manufacturer to consumer, from packaging units form a transport unit as a group package.

For creating a group packaging mostly use gripping devices [1]. Gripping devices designed to capture and hold in certain position packages during its movement.

Gripping devices are one of the widely used functional group packaging equipment modules. All gripping devices, depending on the contact of working parts with packaging elements can be divided into groups [1,2]: mechanical, vacuum, magnetic, combined. To ensure the integrity of soft and semi-rigid packages during group packaging the most promising are combination of gripping devices. Combined gripping devices hold an object by using in the construction two or more kinds of gripping elements which operate simultaneously. Based on the analysis revealed that the most common way of holding packages is a combination of mechanical and vacuum components. Schematic diagram of the combined gripping device mechanical and vacuum type is shown in Fig. 1.

The design of gripping device consists of a body, which is pivotally attached to rails with oscillatory shutters 3 and vacuum element in form of sucker 4.

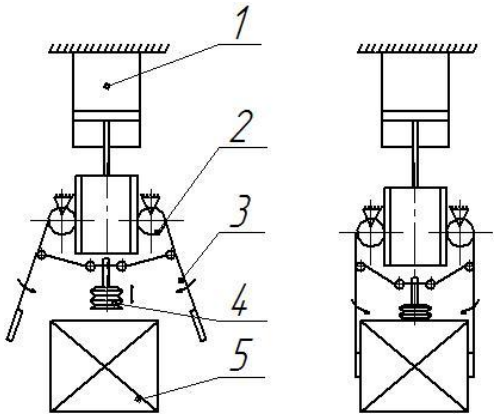

Figure 1. *Schematic diagram of the combined gripping device mechanical - vacuum type with oscillatory movement of shutters: 1 - Pneumatic cylinder 2 - notched-rail transmission, 3 - shutters, 4 - vacuum element 5 - packaging, a- device-initial position, b-device at the time of capturing packaging*

The drive represents by pneumatic cylinder with bilateral action 1. Rod movement of pneumatic cylinder provides simultaneous capturing of packaging 5 by shutters 3 and vacuum gripping element 4.

II. Materials and Methods:

The use of combined gripping devices enables to provide reliable capture and holding packages [3, 4]. In case of additional input into the design of gripping device a control system based on microprocessor technology and backward linkages in the form of control efforts and pressure sensors can get a new design of gripping device, which according to its functional properties classified as mechatronic

gripping module. The main advantage of this module is to redistribution holding efforts between holding elements during movement of packaging, depending on the external environment. The maximum value of applied effort by individual element is limited to physic-mechanical properties of packaging and depends on many factors. Theoretical definition methods of acceptable value of application effort to packaging in such devices is not researched enough. To resolve this problem, consider the problem when combined gripping device which includes a vacuum and mechanical grips, moving package (Fig. 2). In this case, on the package during movement from the combined gripping device, following powers act: $P_{вупр}$ - holding force of vacuum gripping device; $F_{тр}$ _ coupling friction force between packaging and mechanical sponges of capture device. Additional forces act simultaneously on the package that seek to separate or move it relatively to combined capture device. This is the power of inertia $F_{ін}$ and wind resistance force W_n .

Capturing of package can be by two ways that can be characterized by corresponding location of sponges of mechanical gripping device relatively to the direction of movement.

In the first way of capturing sponge of mechanical gripping device directed parallel to displacement of package S (Fig. 2).

The law of motion of package by gripping device in such a way of capturing has the form:

$$\begin{cases} P_{вупр} - mg - F_{ін} \cdot \sin\alpha - W_n \cdot \sin\alpha + 2 \cdot F_{тр} \cdot \sin\alpha = 0 \quad ; \\ 2F_{тр} \cdot \cos\alpha + F_{сц} - W_n \cdot \cos\alpha - F_{ін} \cdot \cos\alpha = 0 \end{cases} , \tag{1}$$

where: $F_{сц}$ - efforts of gripping package with vacuum gripping device;

α - angle of direction of acceleration.

From the other side the value of holding efforts depends on the operating parameters of each of the gripping elements:

$$F_{сц} = \mu(P_{вупр} - mg - F_{ін} \cdot \sin\alpha - W_n \cdot \sin\alpha) \tag{2}$$

$$P_{вупр} = k \cdot f_{еф}(P_1 - P_2 + P_3) \tag{3}$$

$$F_{тр} = f \cdot N \tag{4}$$

where: $f_{еф}$ - effective area of suckerwhich is characterized by lines of contact sucker with the product in m^2; P_1 - atmospheric pressure; P_2 - pressure inside the cavity of vacuum gripping device;

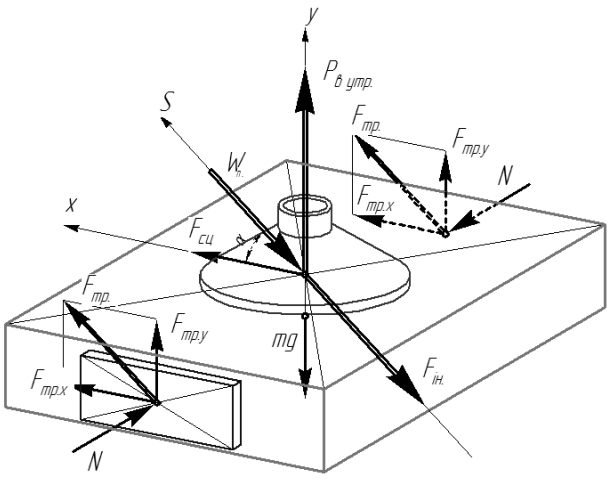

Figure 2. *Diagram of the forces in the process of moving combined gripping devices when the sponges of mechanical gripping device directed parallel to displacement of the package.*

P_3 - drop in pressure that occurs through the porous structure of packing material; k - coefficient of irregularity of roughness material of package around the contact perimeter with the shoulder of vacuum sucker.

Substitute equation (2), (3) and (4) into formula (1), we assume the condition that the acceleration of package is magnitude change and moving happens for a given law of motion. Then we take type of the law of motion, size of vacuum in sucker determine the pressure efforts from sponges of mechanical gripping device on walls of package

$$(P_1 - P_2 + P_3) = \frac{mg + F_{ін} \cdot \sin\alpha + W_n \cdot \sin\alpha - 2 \cdot f \cdot N \cdot \sin\alpha}{k \cdot f_{еф}} \tag{6}$$

$$N = \frac{\mu \cdot m \cdot g + (\mu \cdot \sin\alpha + \cos\alpha) \cdot (F_{ін} + W_n) - \mu \cdot k \cdot f_{еф}(P_1 - P_2 + P_3)}{2 \cdot f \cdot \cos\alpha} \tag{7}$$

To prevent the destruction of packages surface in contact with sponges we introduce the pressure limits in the form of acceptable value for this brands of packaging material. Then the condition for the preservation of type commodity packaging has the form:

$$N \le [N] \tag{8}$$

$[N]$ - acceptable pressure effort on the surface of package material.

The second way of capturing sponges of mechanical gripping device are situated perpendiculary to movement of packing (Fig. 3).

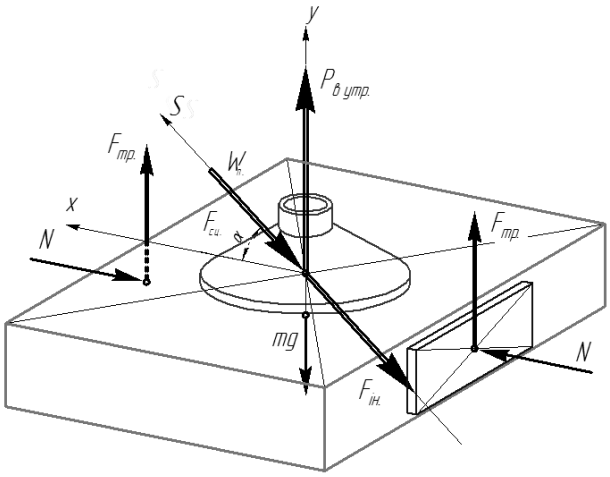

Figure 3. *Diagram of the forces in the process of moving combined gripping device in the case when sponges of mechanical gripping device are situated perpendiculary to movement of package.*

This method of capturing packages involves reduction of holding effort for expense of force compensation for it with separation forces by axis of mechanical sponges capture device. As the pack separation in the direction of specified axis can not be, in the motion equation it is not taken into account.

Motion equation of package gripping device in such a way of capturing has the form:

$$P_{вутр} - mg - F_{ін} \cdot \sin\alpha - W_n \cdot \sin\alpha + 2 \cdot F_{тр} = 0 \quad (9)$$

Substitute equation (2), (3), (4) and (8) in formula (9), previously let us take the view of the law of motion, allow effort from sponges of mechanical gripping device on the walls of package and determine the value of vacuum in sucker

$$(P_1 - P_2 + P_3) = \frac{mg + F_{ін} \cdot \sin\alpha + W_n \cdot \sin\alpha - 2 \cdot f \cdot [N]}{k \cdot f_{еф}} \quad (10)$$

Holding package conditions in such way provides the maximum possible effort of package pressing with mechanical gripping device $[N]$ and adjustment effort of holding vacuum gripping device including package material porosity.

In the case of using soft packages, the priority has effort of capturing vacuum gripping device. If we take maximum permissible value of the vacuum considering the physical and mechanical properties of package from equation (10) we define the package pressing effort of mechanical gripping device. Equation (6), (7) and (10) are the basis of a mathematical model for the system of controlling mechatronic module of gripping device.

III. Results and discussions:

To verify the adequacy of the theoretical results of mathematical models of actual processes was designed and constructed an experimental set.

General view of experimental set is shown in Fig.4.

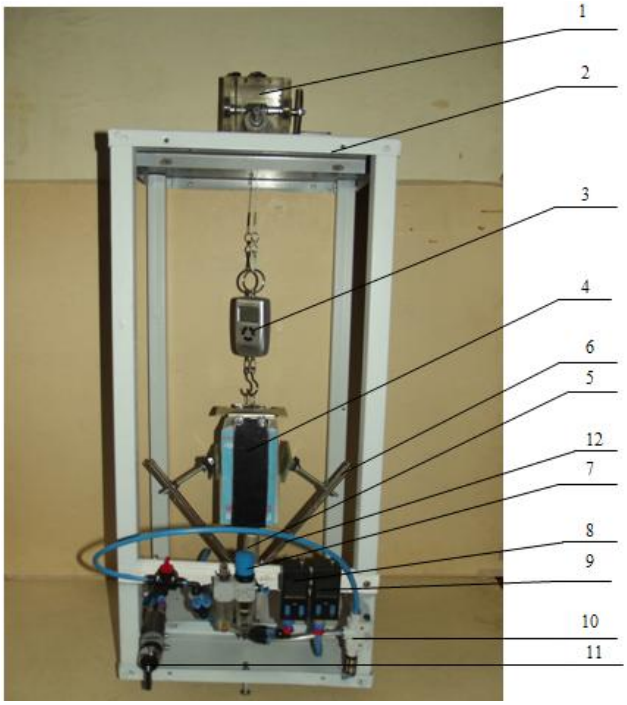

Figure 4. *Experimental set for research of combinedgripping devices: 1 - worm reducer, 2 - body of set; 3 - electronic dynamometer, 4- package holder, 5 - vacuum sucker, 6 - sponges of mechanical gripping element 7 - pressure regulator, 8 - sensor for determining magnitude of the vacuum, 9 - sensor for determining overpressure, 10 - ejector, 11 - gripping device control system, 12-piping system.*

Construction of the set consists of a body 2, combined gripping device, which represents as combination of two devices: the vacuum gripping device 5 and the mechanical gripping device in the form of rail-lever mechanism with 6 sponges. Ejector produces vacuum for the set 10 which is connected to a sucker 5 via pipelines system 12. The depth of the vacuum is measured using an electronic vacuum sensor 8. Pressure control for the mechanical gripping device occurs with an electronic overpressure sensor help 9. The design of experimental set involves applying effort to the packaging separation with the help of flexible elements system which connect the worm reducers 1 with package holder 4. The value of separation effort measured by electronic dynamometer 3.

Based on the four-factor experiment and performed corresponding calculations were obtained criterial equation which allows to determine the value of the allowable separation effort depending on the friction-slip coefficient of sponge gripping elements on cardboard, pressure inside the network, density of boxed cardboard and pressure inside the vacuum grip. About character of factors influence on the permissible separational effort, demonstrate the importance and signs of coefficients:

$$[N] = -18{,}737 + 0{,}172 \cdot \rho + 0{,}432 \cdot P_{пр} + 152{,}525 \cdot f - 4{,}226 \cdot P_{в} - 0{,}043 \cdot \rho \cdot P_{в} - 0{,}08 \cdot P_{пр} \cdot P_{в} - 0{,}81 \cdot \rho \cdot f \cdot P_{в} - 0{,}6 \cdot \rho \times f + 202{,}9 \cdot f \cdot P_{в} \quad (11)$$

where: [N] - permissible separational effort;

f – friction-slip coefficient of rubber sponge gripping elements on cardboard;

$P_{пр}$ – pressure inside the network;

ρ – density of boxed material;

$P_{вак}$ – pressure inside the vacuum grip.

IV. Conclusions

Thus as the results of researches, we can make the following conclusions:

- research results show the advantage of using combined gripping devices on preservation the presentation of package due to the possibility of distribution capturing effort between the gripping elements;
- determined that the difference in the distribution of capturing effort per area unit of surface of the package under the same movement conditions between combined and vacuum gripping devices is up to 56,76%, and between combined and mechanical to 60,1%;
- the results can be recommended in developping new designs of combined gripping devices.

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METHODS OF SIMULATION OF INTERNAL TRANSPORT AND RELOADING MODULES MACHINES FOR PACKING PRODUCTS INTO CARTON PACK

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Abstract: *Existing packaging machines that implement the technological processes of packing of different products with different rheological properties consist of a large the number of functional модулей.Для development of methodology of modeling functional and internal transport of modules was carried out the analysis and synthesis of existing samples of machines for packing products in cardboard boxes.*

Keywords: carton box, washing machine, gift shop packs, conveyor.

I. Introduction

The analysis of market of equipment condition showed on packeting of food foods, that considerable part of food foods was packed in the consumer container of form rectangle (pack), created from a flat cardboard purveyance.

The study of process of packeting of the prepared products in a cardboard pack gives an opportunity to perfect the flowsheet of production of the packed goods, decrease power charges and considerably to promote the productivity of equipment. One of the stages of creation of equipment on packeting of food foods is a choice of chart of internal portage of products and packing. лиз market of equipment conditions on packeting of food foods showed, that considerable part of food foods was packed in the consumer container of form rectangle(pack), created from a flat cardboard purveyance.

It is thus important to take into account continuity of technological process. Also, to provide the comfort of further maintenance of equipment, it is better to choose of the same type transporting devices for treatment of stream of products and packing.

During development of arrangement of packing equipment (machines or lines), it is necessary to take into account the possible variants of moving of products in the internal machine technological module. It should be noted that intracommunications, direction of material streams in an equipment can substantially differ[1].

The model of productive process consists of such elements: the article of treatment is products, packing; a product of treatment is the packed unit, transport-technological system.

The unfolded determination of productive process can be presented so: technically and organizationally well-organized co-operation of equipment and still human labour for the purpose treatment, with the purpose of receipt of necessary product of treatment and functioning of all concomitant productive areas in the set technological mode.

II. Materials and methods

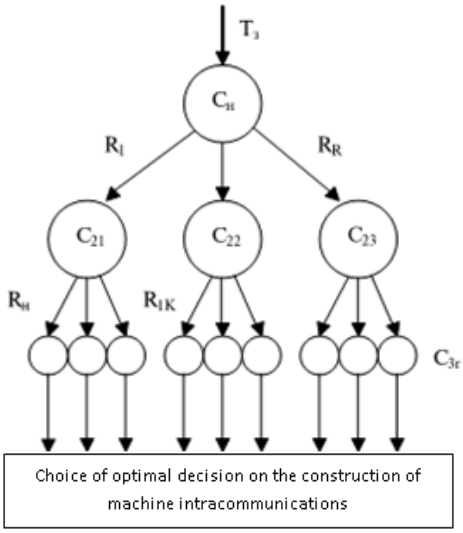

Figure 1. *Model of multilevel process of planning of packing machines of automats with the choice of the most rational decision at last level: Тз is a requirement specification; C _{ij} are operations of synthesis of project decisions(C11, C21.- possible variants of arrangement of knots of the system); Rqk are project variants.*

Model of productive process of packeting of products in cardboard pack.

Technologies of packeting, as a rule, examine as a stream system of processes with the determined

connections. The similar system can be represented as the determined count.

Figure 1. It gives an opportunity to find an optimal decision on machine transport intra-communications.

Examining the typical technological process of packeting of the prepared products in a cardboard pack, it is possible to make the structural model of totality of consistently executable operations Figure 2. The operations of packeting are executed by separate working organs that enter in the complement of the functional modules and shifting devices.It is necessary also to take into account determined sanctify between the elements of process, necessary synchronization of speed of work of the separate functional modules[3].

Planning of such machines-automats is taken to the successive decision of next tasks :

- on the set descriptions of products that is packed and packing unit choose a model and brand packing machine-automat;
- on the set amount of the packed units, find the productivity the chosen packing-packing machine-automat, expect their necessary amount in the general technological system;
- determine optimal arrangement of packing-packing machines-automats and necessary floor-spaces;
- principles of connection and division of all material streams determine, as a result choose a chart and equipment for providing of production necessary basic and auxiliary materials;
- depending on the type of container and packing develop a flowsheet and choose a corresponding equipment for forming of container in a by volume construction, her orientation and transporting in the zone of packing.

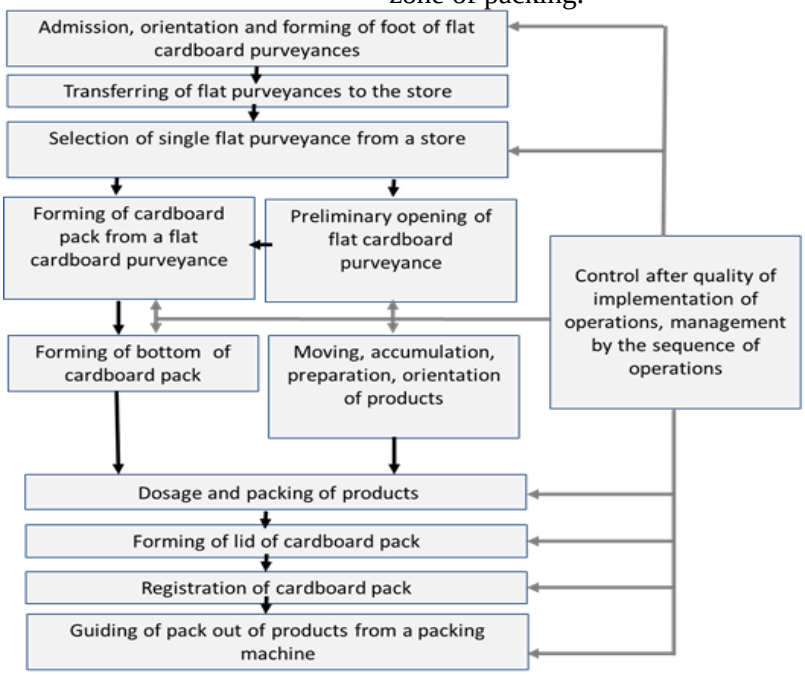

Fig. 2.*Technological process of packeting of the prepared products in a cardboard pack.*

III. Results and discussion

The analysis of machine intracommunications is conducted on the example of technological equipment of existent machines-automats for packing in a cardboard pack.

The process of packet and further investment of the prepared product assembly depends on arrangement of internal-machine transport.

In most machines-automats, flat packages, or the stencilled patterns-purveyances of packages are transported on the transitional system(a lifting conveyer with the device of отбраковки is an accelerating conveyer - step packer) to the machine for a cardboard and passed on a conveyer for the operation of packeting of products. On this conveyer packages are tricked into to the area of the automatic piling of product in the exposed cardboard packs. The flat purveyances of cardboard packs piece perch from a shop, unsealed and passed on a conveyer for forming of volume.

On a next area in the formed pack a product is laid and the overhead and lower valves of packing are closed. Regardless of whether speech goes about a separate machine with semi-automatic office hours, or automated line, in any case it is necessary to provide optimal and individual adaptation of the separate functional modules in a general technological process. A rapid readjust and flexibility of arrangement are impossible without the

successfully worked out internal machine transport both for products and for packing[2].

Conducting the analysis of transformation of machine intracommunications from flat to the spatial modules Figure 3, basic arrangements of the systems were distinguished, where a product and packing can accomplish as simple so difficult flat motion.

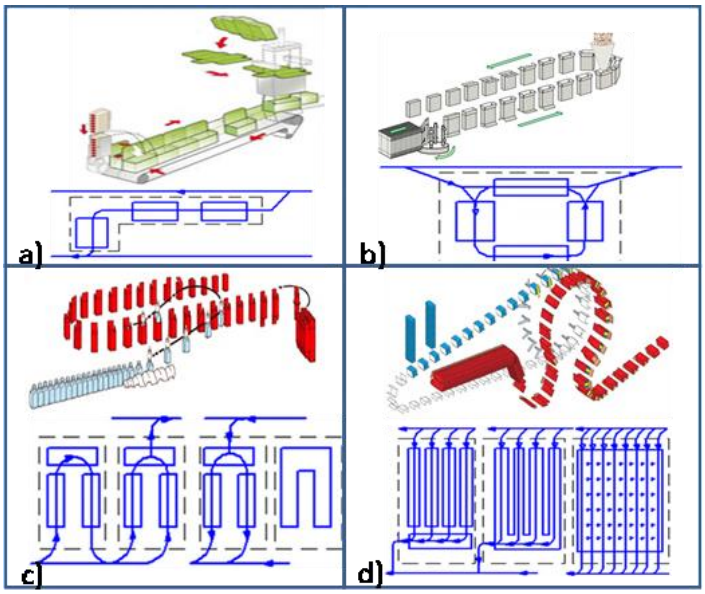

Fig.3. *Charts of machine intracommunications on the example of the technological modules of forming of flat packages in a cardboard pack with the subsequent operations of forming of the consumer packing of products : a) onestream motion of cardboard packs and foods at right angles; b) cyclic motion of cardboard packs and product; c) onestream motion of катонных packs and product on a difficult trajectory; d) multistream difficult motion of cardboard packs and product.*

Combination and correct binding of the functional modules of Figs.3, gives an opportunity to create different configurations internal machines of connections. It facilitates the further adjusting and maintenance of such equipment, and also allows quickly to reconstruct an equipment under. different types of products and packing.

IV. Conclusions

On forming of machine intracommunications, sequence of reproducing of technological operations on the different stages such factors influence: technological possibilities of equipment and knots, amount of the stages of treatment, feature of technology of making of good, great number of operating transitions, feature of packing geometry [4]. Therefore, the synthesis of internal machine transport systems is divided into the row of associate tasks that take into account all these factors. Thus, deciding the task of complex automation of technological process with introduction of flexible technologies and possibility of rapid readjust of equipment - it is appropriate to use module principle of forming of technological equipment. It gives an opportunity to take into account priority of operations of treatment (packing), expect and choose the route of wares and packing, choose the knots of certain arrangement for providing of rational technological process on a production.

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ION EXCHANGE PROPERTIES OF JERUSALEM ARTICHOKE STEMS

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Abstract. *Experiments on the demetalization of wine wth flour made from Jerusalem artichoke stems were conducted under static and dynamic conditions. The used plant sorbent proved to lead to effective wine purification regarding the ions Cu^{2+}, Mn^{2+} and Fe^{2+}. The highest degree of extraction (98%) was obtained in manganese with the use of flour washed with hydrochloric acid in ethanol under static conditions.*

Keywords: Jerusalem artichoke, wine, ion exchange properties

I. Introduction

Jerusalem artichoke (Helianthus tuberosus L.) is a perennial tuberous plant of the Asteraceae family. What differentiates it from most conventional plant raw materials used in food industry is its rich carbohydrate composition and more importantly the high inulin content in its tubers [1,8]. Apart from inulin, Jerusalem artichoke contains a substantial amount of pectins, cellulose, hemicellulose and free mono- and oligosaccharides inluding oligofructose [3]. A characterization of the polyuronide content of some sorts of Jerusalem artichoke growing on the territory of Bulgaria was made in our previous research [2]. The study showed that pectins are found in all parts of the plant with the highest content being in the tubers and stems (13,5% and 12,4 % a.d.m.* respectively). Other literary sources show that the content of easily and hard hydrolysable polysaccharides and lignin-like substances in the stems is 23,5% a.d.m., 32,5% a.d.m. and 17,7 % a.d.m. respectively [4].

It's a well-known fact that pectins and some other components of the plant cells and tissues (including lignin) have the ability to combine various metal ions [5, 6]. This fact, the rich carbohydrate composition of Jerusalem artichoke and its biological and cultivation characteristics (it grows quickly irrespective of soil, weather conditions and cultivation techniques) made it worth researching the ion exchange properties of the stems and their application in wine demetalization.

*a.d.m. – absolute dry matter

In some wine sorts the removal of metals such as copper, iron, manganese, zink, etc. is a compulsory technological procedure. In food industry it is usually done with potassium ferrocyanide, potassium phytate and others. Literary sources have very few data on the ion exchange properties of the stems of Jerusalem artichoke [7].

The aim of this paper is to carry out experiments on wine demetalization with flour made from Jerusalem artichoke stems.

II. Materials and methods

Stems of Jerusalem artichoke were used for the demetalization of wine. The stems were gathered during the ripening period (the end of October, 2012), then they were cut, dried, ground (in an electric grinder) and screened (laboratory sieve 0.80). In some of the experiments the raw material was washed with hydrochloric acid in ethanol: 100 cm^3 5% solution of hydrochloric acid in ethanol (70%) were added to the flour and the mixture was strirred with an electromagnetic stirrer for 1 hour at room temperature. Then the sample was filthered through a Büchner funnel and washed with ethanol (70%) to neutral reaction. After that it was washed with ethanol (96%) and dried at 50 ^{0}C.

Dry white wine bought from a big chain supermarket was used in the experiments.The metals were added to the wine in the form of water solutions of salts ($CuSO_4$, $MnCl_2$, $FeSO_4$).

The research on the demetalization ability of the flour was conducted under static and dynamic conditions as follows:

Variant A. 10 g of the raw material were put in an Erlenmeyer flask, 200 cm^3 of the wine with the

respective salt solution was added, the mixture was stirred, left undisturbed for 30 min at room temperature and then filtered.

Variant B. 10g of the raw material were put in a chromatographic column and splashed with wine, then 200 cm^3 of the wine with the respective salt solution was let through. The eluate was collected in a flask and the content of the metal ions was determined.

In both variants the salts were dosed in such a way that the content of the respective metal was about 15 mg/dm^3.

The analysis of the metals was performed with an atomic absorption spectrometer UNICAM, Solar 936.

The degree of extraction (degree of purification, α) of the metal ions was determined with the formula:

$$\alpha = \frac{C_m - C_{m1}}{C_m} 100\%, \quad (1)$$

where Cm - mass concentration of the metal ions in the initial solution, mg/dm^3;

Cm_1 – mass concentration of metal ions in the demetalized solution, mg/dm^3

III. Results and discussion

Table 1 shows the results from wine demetalization under static conditions.

Table 1. *Wine demetalization with flour from stems of Jerusalem artichoke – vataint A*

Type of metal	Content, mg/dm^3			Degree of extraction, %
	Check sample	Sample A	Sample B	
copper	0,48	15,22	1,21	92,1
manganese	0,58	15,97	1,68	89,5
iron	0,63	14,84	1,36	90,8

The content of the three metals in the initial wine (the check samples) is under 1 mg/dm^3. After the addition of the salt solutions the concentration rose to 15 mg/dm^3 (sample A). In the demetalized wine (sample B) the content of the metal ions is under 2 mg/dm^3. The table shows that very good results were achieved after the use of the sorbent. For example the copper content was reduced from 15,22 mg/dm^3 to 1,21 mg/dm^3 and the degree of extraction α is 92,1%. The high demetalization abilty of the stems is probably due not only to the presence of pectins but to all the other substances having ion exchange properties. It is important to have in mind that ion exchange is frequently accompanied by adsorption.

In the next experiment flour washed with hydrochloric acid in ethanol was used (Table 2) due to some soluble components from the flour passing to the wine (e.g. pigments) and changing its organoleptic characteristics.

Table 2. *Wine demetalization with washed flour from stems of Jerusalem artichoke – variant A*

Type of metal	Content, mg/dm^3			Degree of extraction, %
	Check sample	Sample A	Sample B	
copper	0,48	15,31	0,37	97,6
manganese	0,58	14,67	0,29	98,0
iron	0,63	14,50	0.45	96,9

Demetalization here was again conducted under static conditions (varaint A). The results are better in comparison with the previous experiment. The degree of extraction in the three samples is remarkably high – 96% and in manganese it is 98%. The washed raw material didn't cause any considerable changes to the colour or the other organoleptic characteristics of the demetalized wine.

Tables 3 and 4 show the results from experiments on wine demetalization under dynamic conditions (variant B). It is obvious that in this variant there is a decrease in the removal of the metal ions. For example the degree of extraction of manganese with unwashed flour under dynamic conditions is 81,6 % (Table 3) while the degree of extraction with the same flour under static conditions is 89,5%. The results with the washed flour (variant B) also show that the values of α are comparatively lower than those in variant A (Table 2). Nevertheless it can be concluded that the experiments under dynamic conditions are also satisfactory. As a whole the removal of manganese with washed flour under static conditions proved to be the most efficient.

Table 3. *Wine demetalization with flour from stems of Jerusalem artichoke – variant B*

Type of metal	Content, mg/dm^3			Degree of extraction, %
	Check sample	Sample A	Sample B	
copper	0,38	15,70	2,63	83,2
manganese	0,27	15,09	2,78	81,6
iron	0,51	14,32	2,09	85,4

Table 4. *Wine demetalization with washed flour from stems of Jerusalem artichoke – variant B*

Type of metal	Content, mg/dm^3			Degree of extraction, %
	Check sample	Sample A	Sample B	
copper	0,38	14,41	1,85	87,2
manganese	0,27	14,63	2,18	85,1
iron	0,51	15,18	1,76	88,4

IV. Conclusions

1. It was determined that flour made from dried stems of Jerusalem artichoke has high dematalization ability regarding the ions of Cu

(II), Mn (II) and Fe (II) and can be succesfully used for the purification of wine from these ions.

2. The highest degree of extraction of the metal ions was achieved under static conditions (10 g sorbent with 200 cm^3 solution for 30 min)
3. It was established that in both variants of the experiment (static and dynamic conditions) the use of flour washed with hydrochloric acid in ethanol leads to better results – more efficient removal of the metals and preservation of the organoleptic characteristics of the wine.
4. Regarding the three metals, the highest degree of purification is achieved in manganese (α=98%) with washed flour under static conditions.
5. Some of the parameters of the process under dynamic conditions can be optimized in order to achieve a more complete extraction of the metal ions.

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EXTRUDED PROTEIN TEXTURATES PRODUCTION

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Abstract. *The recipe of legumes mixture is validated. A mathematical model of the biopolymer melt flow in extruder molding channel is given. Extrusion process kinetics is evaluated and the chemical composition of extruded texturate is defined. The design of the extruder with a dynamic die is worked out.*

Key words: extrusion, texturate, mathematical model

I. Introduction

One of the most promising ways to improve the technology of functional products with high nutritional value (sausages, ravioli, meatballs, etc.) is the production of extruded protein texturates derived from a mixture of legumes. Textured vegetable proteins are simplified form of meat substitutes, as they are similar to meat in appearance, texture and taste. Extrusion technology gives an opportunity to change the structure, composition and nutritional value of the protein-starch complex quantitatively and qualitatively, which increases the digestibility of extruded texturate.

II. Making mixtures

The purpose of this paper is the choice and validation of a mixture of leguminous recipe; obtaining on its base extruded protein texturates with high biological value and balanced amino acid composition and the development of extruder design for their production.

The following factors were taken into consideration for scientific validation of the choice of new multicomponent mixtures of legumes with an enhanced protein content: firstly, the necessity of maximum enrichment of extruded texturate containing mainly carbohydrates, protein components in order to achieve their therapeutic and prophylactic or physiological doses, secondly, the necessity to obtain a product with high nutritional and biological value, and thirdly, to achieve a palatability and attractive structure. In addition, along with a developed structure of extruded texturate it is necessary to strive for obtaining of food products of a balanced nutritive and biological value.

Lupine beans, lentils were used as a raw material.

The following calculation was used to develop optimal mixture content of leguminous crops. In the first stage the mixture components are chosen, their chemical composition is determined. Then optimization criteria for choosing the best combination of components of the mixture using a special algorithm is calculated. Data processing was carried out using a mathematical software complex, on the basics of which rational content of lupine and lentil beans in the initial mixture in the following proportions: 15,3 : 14,5 : 43,2 (by weight) is defined.

Initial types of legumes were disintegrated in a grinder and sifted through a sieve number 2 for alignment of the particle size distribution of 0.3 to 0.6 mm, and then charged into the mixer and mixed at a ratio of components 15,3 : 14,5 : 43,2 by weight and then moisten up to 14...18%. Next the prepared mixture of legumes was treated by a single screw extruder at a product temperature prior to die of 403-408 K and a pressure in the predie region of the extruder of 5,5-6,2 MPa. Under the influence of pressure and temperature the proteins are denatured, which is an intramolecular phenomenon characterized by physical rearrangement of internal connections. Concurrently the violation of order of the molecule internal structure quantified by changes in physico-chemical properties of proteins (solubility, hydration capability, solution viscosity, resistance to the enzymes action, biological activity, etc.) [1] takes place. In the duration of the process of protein-containing materials thermomechanical degradation in extruder globular structure of the protein molecule is converted into a fibrillar one. As a result of thermomechanical impact long protein molecules are broken into smaller polypeptide and peptide ones.

Usage of dynamic die achieves high shear forces that lead to intensive processing of protein-containing substances.

III. Mathematical modeling of the biopolymer melt in the molding channel of the extruder dynamic die

To study the distribution of extrudate velocity and pressure along the length of the die molding channel at different draw bar rotation velocity and the gap between draw bar and die holes cones the modelling of biopolymer melt motion in the molding channel

extruder dynamic die was conducted. To solve the problem of biopolymer extrudate motion in the die molding channel flow model at low Reynolds numbers and the Boussinesq approximation were used. As a result of investigation it was found that the motion mode of the biopolymer melt in the extruder molding channel is laminar, so the mathematical model "laminar fluid" was chosen. Given the fact that the product stays in the region of interest for short span of time (τ = 5...7 s), and that the extruder housing is equipped with a constant temperature maintaining system the process can be regarded as isothermal [2]. The product enters the forming assembly in the form of homogeneous molten mass and equation of mass transfer can therefore be neglected. To model the biopolymer melt flow dynamic die solid model was established by the system of automatic modeling Kompas -3D V11, which can be imported into Flow Vision.

For the numerical solution of the basic equations the Flow Vision uses the finite volume method, which is based on the conservative calculation schemes for partial unsteady-state equations. Finite volume method is reduced to the approximation of a continuous medium with an infinite number of degrees of freedom of a set of elements that have a finite number of degrees of freedom. Then relationship is established between these elements.

The selected model contains the following equations :

Navier-Stokes equation where the continuity equation.

$$\frac{\partial \upsilon_x}{\partial \tau}+\frac{\partial\ \upsilon_x{}^2}{\partial x}+\frac{\partial\ \upsilon_x\upsilon_y}{\partial y}+\frac{\partial\ \upsilon_x\upsilon_z}{\partial z}=-\frac{\partial P}{\partial x}+\frac{1}{\mathrm{Re}}\nabla^2\upsilon_x,$$

$$\frac{\partial \upsilon_y}{\partial \tau}+\frac{\partial\ \upsilon_x\upsilon_y}{\partial x}+\frac{\partial\ \upsilon_y{}^2}{\partial y}+\frac{\partial\ \upsilon_y\upsilon_z}{\partial z}=-\frac{\partial P}{\partial y}+\frac{1}{\mathrm{Re}}\nabla^2\upsilon_y,$$

$$\frac{\partial \upsilon_z}{\partial \tau}+\frac{\partial\ \upsilon_x\upsilon_z}{\partial x}+\frac{\partial\ \upsilon_y\upsilon_z}{\partial y}+\frac{\partial\ \upsilon_z{}^2}{\partial z}=-\frac{\partial P}{\partial z}+\frac{1}{\mathrm{Re}}\nabla^2 w,$$

where $\nabla^2\upsilon_x=\frac{\partial^2\upsilon_x}{\partial x^2}+\frac{\partial^2\upsilon_x}{\partial y^2}+\frac{\partial^2\upsilon_x}{\partial z^2}$,

$$\nabla^2\upsilon_y=\frac{\partial^2\upsilon_y}{\partial x^2}+\frac{\partial^2\upsilon_y}{\partial y^2}+\frac{\partial^2\upsilon_y}{\partial z^2},$$

$$\nabla^2\upsilon_z=\frac{\partial^2\upsilon_z}{\partial x^2}+\frac{\partial^2\upsilon_z}{\partial y^2}+\frac{\partial^2\upsilon_z}{\partial z^2};$$

continuity equation

$$D\equiv\nabla\cdot V\equiv\frac{\partial\upsilon_x}{\partial x}+\frac{\partial\upsilon_y}{\partial y}+\frac{\partial\upsilon_z}{\partial z}=0\cdot \qquad (1)$$

In the task at hand the following boundary conditions were used (Fig. 1):

1. The product melt input into the die hole channel: the type of border - input/output, the type of boundary condition - normal speed 0,022 m/s . At the boundary of the region the velocity vector normal component is specified (υ_{nw}) $\upsilon|_n=\upsilon_{nw}$. If $\upsilon_{nw}>0$, then the boundary condition is treated as "input". If $\upsilon_{nw}<0$, then the boundary condition is treated as an "output". In the process of calculating a negative value υ_{nw} is reset in accordance with the following rule $\upsilon_w^{out}=-\sum\upsilon_w^{in}S^{in}/\sum S^{out}$, which ensures the condition of the mass balance. Here S^{in} and S^{out} – the regions of "input"/"output" boundary surfaces, respectively.

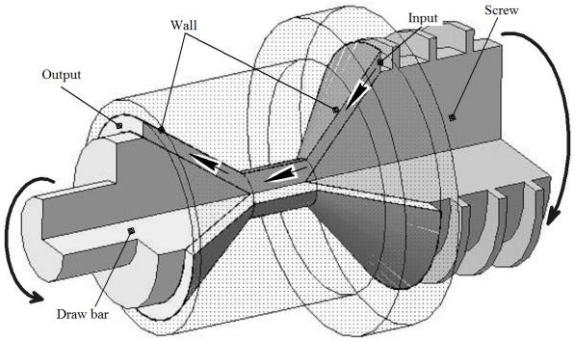

Fig. 1. *Design model of the biopolymer melt motion in the extruder dynamic die molding channel*

2. Die hole channel: the type of the border – a wall, the type of boundary conditions – a wall, at the region boundary adhesion condition is specified $\upsilon|_w=0$.

3. Product yield: the type of border - free output, the type of boundary conditions - zero pressure/output. Velocity at the computation region border of the field is specified according to the following rules:

- direction of the velocity vector is determined in a computational cell adjacent to the boundary;
- if the velocity vector is directed into the computational region, the normal component of the velocity is set to zero;
- if the velocity vector is directed out of the computational region, then normal derivatives of the velocity vector components are set to zero.

$$p|_w=0,\quad \upsilon,n\ >0;\qquad \upsilon|_w=\upsilon_{tw};$$

$$\upsilon, n < 0; \qquad \Delta\, \upsilon_i, n \Big|_w = 0 \cdot$$

here *n* - the normal to the boundary, υ_{tw} - the tangential velocity component at the boundary.

4. The rotating screw: the type of the border - a wall, the type of boundary conditions - tangential twist. This boundary condition specifies the velocity vector υ_k with tangential component to the boundary surface (the normal component is absent $\upsilon_n = 0$). The direction of the tangential velocity component is determined by screwdriver ruleapplied to the vector. The actual design is a flat boundary facets. Therefore, the velocity determined by the rule of thumb, may have normal to the facet component. In the calculations this component is assumed to be zero. Occurring error can be reduced by improving the quality of surface representation of the facet. We set the screw rotation velocity $\omega = 37,7$ rad/s.

5. The rotating draw bar: the type of border - a wall, the type of boundary conditions - tangential twist. This boundary condition specifies the velocity vector υ_k, having tangential component to the boundary surface (the normal component is absent $\upsilon_n = 0$). The direction of rotation of the draw bar and the screw is determined by screwdriver rule and the degree twist sign): $\omega > 0$ - "direct" rotation; $\omega < 0$ - the "reverse" rotation.

The direction of the tangential velocity component is determined by screwdriver rule applied to the vector. The actual design is a flat boundary facets. Therefore, the velocity determined by the screwdriver rule, may have normal component to the facet. In the calculations component is assumed to be zero. We specified the velocity of the draw bar $\omega = 0...157$ rad/s. In the mathematical model the melt with the following properties: density of 1290 kg/m^3 and the dynamic viscosity of 20 kPa·s was used. After specifying the parameters of the numerical modeling method the program for generation an updated version of the calculation grid and variant calculations on specified conditions is run. As a result, the behavior graphs of extrudate velocity and pressure along the extruder dynamic die molding channel at different rotating velocities of draw bar with the gap of 1.0 mm, 1.5 mm, 2.0 mm (Fig. 2 , 3, 4) are constructed.

In the extruder dynamic die molding channel three regions can be singled out: I - region bounded by a screw cone; II - the region between the screw and draw bar cones; III - region bounded by draw bar. With a gap size of 1,0 mm (Fig. 2) pressure and velocity change as follows:

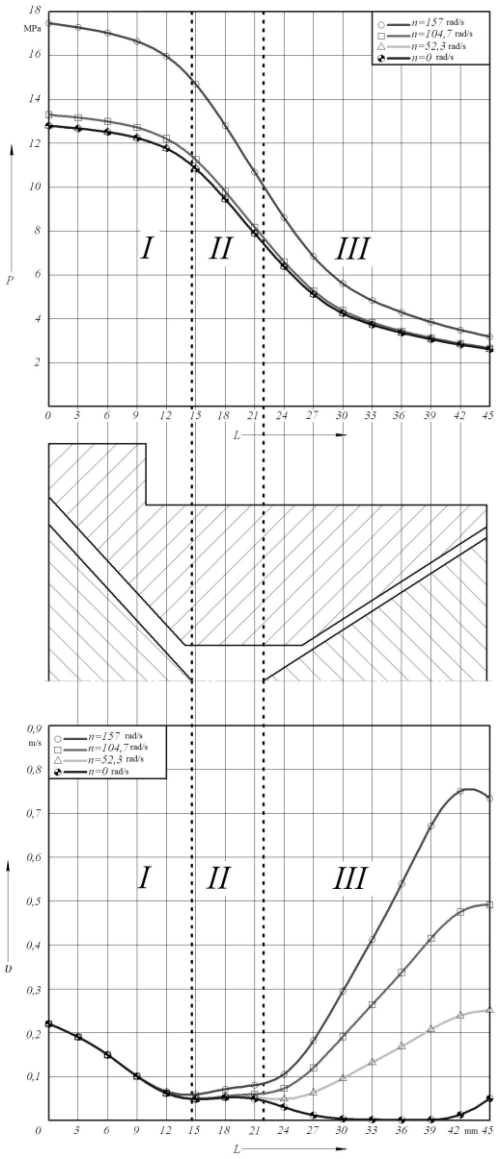

Fig. 2. *Pressure and velocity graphs of the extrudate along the extruder dynamic die molding channel die at different rotating velocities of draw bar with a gap of 1 mm*

in the region I the gradual reduction of pressure on the 20 % of the initial value takes place at the draw bar rotation velocity 0 ... 157 rad/s, the product melt motion velocity modulus decreases in the duration. This is due to the reduced impact of the rotating screw cone, as the main velocity component of the die is the peripheral velocity. In the region II the pressure sharply decreases by 33 % at 157 rad/s and by 23% - at 0...104,7 rad/s. The velocity slightly increases due to the increasing influence of the rotating draw bar, biopolymer melt is involved in a helical motion.

This effect occurs at 104,7...157 rad/s, at lower rotating velocities it is minimal. In region III the pressure is further reduced by, respectively 47 % and

57 %. The velocity meanwhile sharply increases due to the high rotating velocity of draw bar. Pressure reduction behavior at draw bar rotating velocity 0...104,7 rad/s remains unchanged, but at 157 rad/s, sharp increase of die pressure occurs:

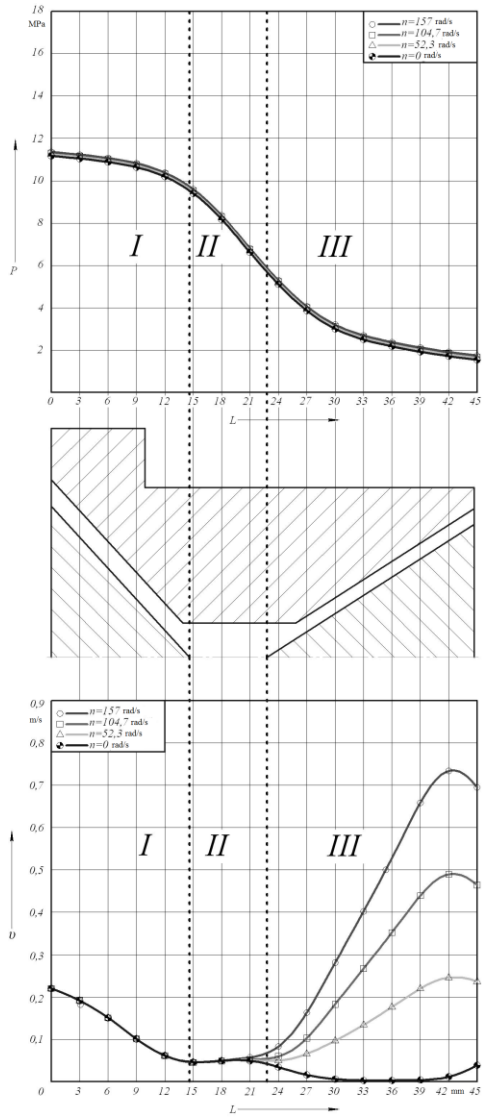

Fig. 3. *Pressure and velocity behavior graphs of the extrudate along the extruder dynamic die molding channel die at different rotating velocities of draw bar with a gap of 1,5 mm*

at draw bar rotation velocity 0 ... 104.7 rad/s extrudate pressure is 12,5...13,5 MPa, while at 157 rad/s – 17,5 MPa. In case of a gap size of 1,5 mm (Fig. 3) pressure changes as follows: in the region I the gradual pressure reduction by 20 % of initial value at the draw bar rotation velocity 0 ... 157 rad/s, in the region II pressure is sharply reduced by 37 % at 0...157 rad/s; in region III further pressure reduction by 43 % occurs. The initial pressure is 11 ... 11,5 MPa at a draw bar rotating velocity of 0...157 rad/s. Fig. 3 shows that the pressure reduction behavior is only slightly dependent on the draw bar rotation velocity. The velocity modulus in the region I have a similar behavior to the gap of 1.0 mm; in region II it remains constant.

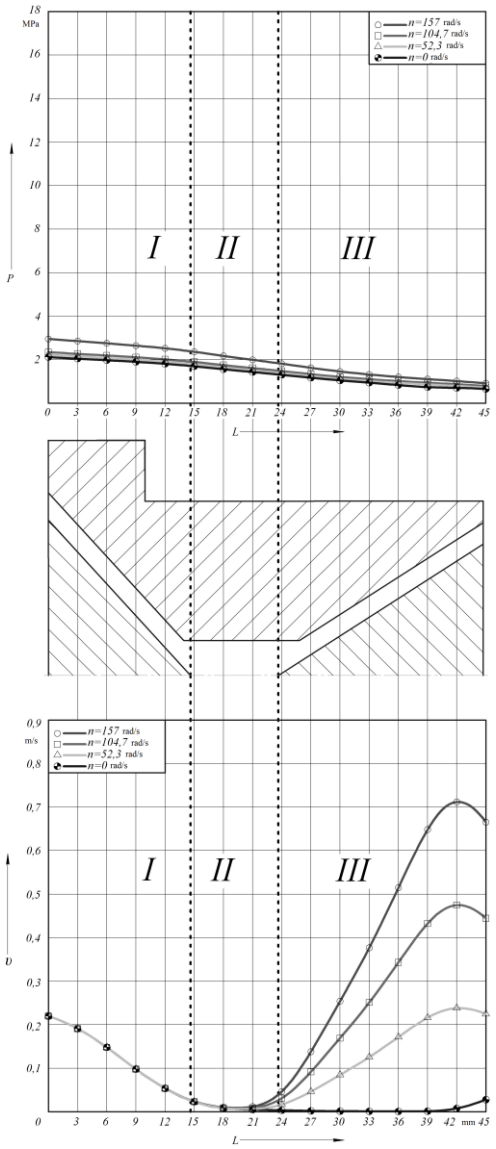

Fig. 4. *Pressure and velocity behavior graphs of the extrudate along the extruder dynamic die molding channel die at different rotating velocities of draw bar with a gap of 2 mm*

Therefore, in case of further increase in the gap the effect of rotating draw bar on the biopolymer melt decreases, in region III the value of velocity slightly reduces. With a gap size of 2,0 mm (Fig. 4), pressure reduces linearly over the entire length of the extruder molding die.

The results of mathematical modeling were as follows:

1. Recommended gap between the draw bar and die hole cones is 1,0...1,5 mm. It is established with a bigger gap the required value of extrudate pressure in

the molding channel of the dynamic die is not achieved. When reducing the gap size a sharp increase in pressure takes place, which significantly affects the quality of the finished product.

2. The rational draw bar rotating velocity is established to be 104,7...157 rad/s, by which thermomechanical degradation of protein-containing substances in the gap between the outer surface of the draw bar and the inner surface of the forming die occurs most rapidly.

IV. Extruded texturate chemical composition determination

The chemical composition of lupine beans, lentils and extruded texturate of these products (the ratio of lupine beans and lentils 15,3 : 14,5 : 43,2 by weight) (the content of substances in 100 g) are presented in table 1.

Table 1. *The chemical composition of lupine beans, lentils and extruded texturate*

Substances	Product			The product mixture of lupine, beans and lentils	Extruded texturate lupine
	lupine	beans	lentils		
Protein, %	26,3	21	24	21,95	28,79
Water, %	14	14	14	14	5
Valine, g	0,92	1,12	1,27	0,5	0,91
Isoleucine, g	1,22	1,03	1,02	0,45	0,79
Leucine, g	2,25	1,74	1,89	0,81	1,42
Lysine, g	1,05	1,59	1,72	0,68	1,28
Methionine, g	0,51	0,43	0,51	0,2	0,27
Threonine , g	1,18	0,87	0,96	0,41	0,91
Tryptophan, g	0,21	0,26	0,22	0,1	–
Phenylalanine, g	1,17	1,76	2,03	0,78	1,02

Evaluation of amino acid balance and biological value of the extruded texturate was conducted by the amino acid score difference coefficient (ASDC) and biological value (BV) of the protein (Fig. 5). The evaluation of the of amino acid content and biological value of the individual components of the mixture (lupine, beans and lentils) and extruded texturate (Fig. 5) by the amino acid score difference coefficient and biological value prove extruded texturate protein balance.

As a result of the research extruded texturate in a form of flakes with circular cross section, smooth surface and poor porosity (Fig. 6) was obtained. Extruded texturate had satisfactory consumer properties: light gray in color, taste and aroma corresponded to the raw materials.

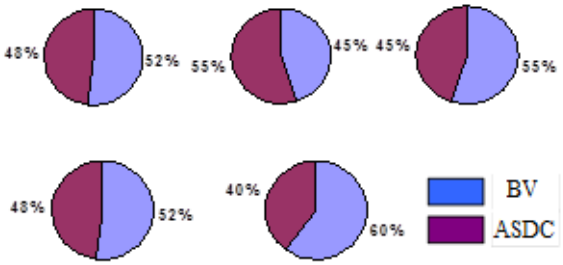

Fig. 5. *Comparative characteristics of biological value (BV) and the amino acid score difference coefficient (ASDC): a - lupine, b - beans, c - lentils, d - the original mixture, e - extruded texturate*

To evaluate the quality characteristics of extruded texturate their physicochemical properties were investigated: swelling (water absorbing ability), solubility and water-holding capacity (Table 2). These important indicators that demonstrate texturate ability to bind water and dissolve in it characterize its carbohydrate composition, and consumer properties and partially absorption of the product. Other physico-chemical characteristics are also in line with the regulations for this category of products (Table 2). Energy value of obtained product is 795,65 kJ/100 g

Fig. 6. *Extruded texturate*

Table 2. Physico-chemical characteristics

Indicator name	Extruded texturate
Swelling, g/g	21,6
Water-holding capacity, g/g	55,45
Moisture, %	6,6
Weight content of total sugars on a dry basis, %	15,3
Fat content on a dry basis, %	1,98

V. Development of extruder with a dynamic forming die design

For the implementation of technology of the extruded protein texturates of legumes mixture extruder with a dynamic forming die design was developed. The extruder consists of a housing (1), screw (2),

forming die (3), draw bar (4), discharge chamber (5), bearing assembly (6), sheave (7) (Fig. 7). Screw (2) is driven by the gear system (not shown in Fig. 3). Draw bar (4) consists of three pairs of tandem cone and cylindrical parts (Fig. 3). Gradually expanding, curved counterclockwise rectangular channels of varying depth are made on the outer surface of the first conical part. The first cylindrical part whose surface is provided with two sets of triangular projections of rectangular cross-section is situated after the first conical part of draw bar (4).

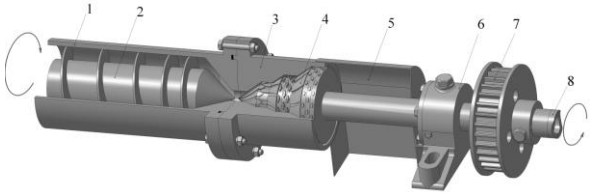

Fig. 7. *Extruder with a dynamic forming die : 1-housing, 2-screw, 3-forming die, 4-draw bar, 5-discharge chamber, 6-bearing assembly, 7-sheave, 8-former*

The draw bar (4) second cone part has a frustoconical shape on the outer surface of which curved in the clockwise direction, gradually tapering rectangular channels of variable depth are made. The second cylindrical part of the draw bar (4) where rhomboid rectangular projections arranged chequer-wise is situated after the second conical part of draw bar (4). The third conical part of the draw bar is situated after the second cylindrical part of the draw bar. The second conical part of a draw bar has a frustoconical shape on the outer surface of the cone curved in a counterclockwise direction; gradually tapering rectangular channels of variable depth are made. The third cylindrical part on the surface of which the diamond-shaped projections of rectangular cross-section are made, situated chequer-wise with the longer pitch than projections on the second cylindrical part of the draw bar is situated after the third conical part of the draw bar. Draw bar (4) is driven through a sheave (7).

The rotating draw bar (4) has the capability to make axial oscillatory movements along the axis of the extruder at a certain frequency due to the fact that at the end of the draw bar shaft former profile (8) is made which cooperates with the thrust support roller. The design of the bearing assembly (7) provides axial vibration of the draw bar (4). Vibrational axial movements of the draw bar (4) in forming die (3) with some rotation velocity have a cavitational impact on the product melt, causing additional destruction of a solid structure of protein and starch grains. The internal profile of the internal conical and cylindrical parts forming die (3) and the draw bar (4) are chosen so that the working gap between them has a shape of a conical annular passage that promotes more intensive compression of the extrudate during its advancement in the working gap.

The design of the fixed forming device (3) and a draw bar (4) rotating inside gives an opportunity to significantly enhance the capability of the extruder by controlling the location time of the extrudate in the working gap by changing the rotation velocity of the screw (2) and the draw bar (4). This increases the heat in the extrudate and intensive mechanical stress on him and causes significant shear deformation in the product, therefore, helps to ensure a homogeneous melt texturate. Simultaneously, at the outlet of the working gap between the draw bar (4) and forming die (3) texturate is divided into particles of various shapes and sizes. Due to the rapid depressurization and explosive moisture evaporation at the extruder outlet to the discharge chamber (5) texturate swells, increasing in volume.

VI. Conclusion

Thus, the suggested use of an extruder with dynamic die can improve the degree of protein denaturation due to the intensification effect of the compressive forces in the gap between the outer surface of the draw bar and the inner surface of the forming die. Occurring multiple material shear deformations allow to obtain a homogeneous melt texturate. Extruded texturates are recommended to use as ingredients in the manufacture of functional foods.

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THE STUDY OF CORRELATION BETWEEN TECHNICAL PARAMETERS OF THE MIXER AND THE QUALITY INDICES OF DOUGH

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Abstract: *Kneading operation aims to achieve a homogeneous mixture of raw and auxiliary materials and at the same time obtain dough with specific structure and properties. Dough formation arises due to physical and colloidal processes, factors which have a big influence on energy consumption. Due to present situation in energetic sphere, it has been decided to make a study and determine the optimal properties and conditions of dough kneading process. Using a laboratory mixer, approached to an industrial one, and different measuring instruments, it has been modeled, studied and determined the optimal kneading parameters, namely the dependence of energy consumption on working tool speed. There were obtained curves of specific energy consumption dependence during kneading process for different working body speeds. The result of the study show that the increase of the working speed from about 200 up to 400 min^{-1} does not cause a significant increase in energy consumption, and even, in some cases it decreases, while further speed increasing causes a significant increase of power.*

Keywords: technical parameters of the mixer, quality indices of dough, energy consumption.

I. Introduction

Qualitative dough mixture assumes an attaining of a homogeneous structure and properties of specific viscosity and elasticity.

Dough formation arises due to physical and colloidal processes:

- physical processes are related to mechanical action during dough kneading and temperature rising;
- colloidal processes are related to the formation of gluten and dough colloidal structure, components hydration and proteins deflocculating process.

Therefore there was a close correlation between physical and colloidal processes in order to obtain qualitative dough.

Knowing the gluten content and its role in dough shaping, it was supposed the existence of a link between colloidal processes and kneading intensity, which determine energy consumption and final product quality [1].

Rheological properties of the dough have an important contribution on the quality of bakery and pastry products. The final quality of the products mentioned above depends not only on the quality of raw materials, but also on following all stages of the technological process. Knowing the rheological parameters of bakery flour and rheological parameters of the dough, particularly helps people who work in this area, in order to appreciate technological and functional parameters of the equipment which processes this dough and allow them to optimize the baking process.

II. Materials and methods

Dough kneading process was performed with a "ZELMER" discontinuous mixer with two vertical blades and shaft furniture. The blades are spiral shaped, this fact presenting its area of work – dough kneading.

Mixer's bowl has a capacity of 3 liters. Also this mixer allows choice of 4 speeds: 192; 290; 385 and 480 min^{-1}, with a nominal power equal to 160 W, and maximal power 400 W.

The mixer was equipped with an ammeter (measurement accuracy ± 0,025 A), a voltmeter (measuring precision ± 5 V) and a voltage regulator to provide needed voltage in limits of input voltage. Electricity intensity and voltage, during kneading process, were registered at intervals of 1 minute.

For weighing raw materials was used an electronically scale with maximal capacity of 300 g.

The research has been made in „Agro-alimentary" scientific laboratory, Technical University of Moldova, provided with all the necessary equipment.

For the study was used high quality wheat flour containing 25% and 27% gluten and 14% humidity. For one portion of dough kneading were used 200±10 g flour, 3±0,15 g salt, 6±0,15 g yeast and 110±0,5 ml water.

Amount of gluten in the flour content was determined by the "hand washing gluten flour" method according to [STAS 90-77], [GOST 27839-88].

III. Results and discussions

After processing the experimental data, there were obtained curves of specific energy consumption dependence during kneading process for different working speeds body (Figure 1(a) and 1(b)).

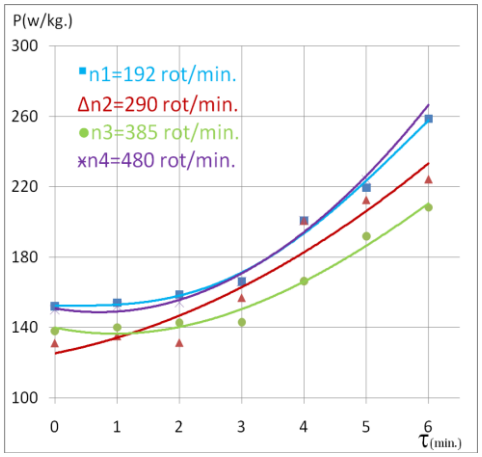

Figure 1(a) *Dependence of energy consumption by time for different speed of the working blade for dough with 25% gluten content*

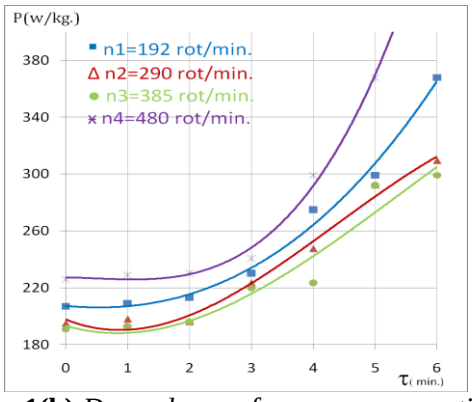

Figure 1(b) *Dependence of energy consumption by time for different speed of the working blade for dough with 27% gluten content*

From obtained graphs is observed that regardless of flours gluten content, once increasing process duration, energy consumption increases. This is due to changes in time of dough properties, and hence increased resistance to blades movement through product.

Mathematical description of the correlation between kneading duration and energy consumption is shown in (Table 1).

Table 1. *Correlation between kneading duration and energy consumption*

Working tool speed, min^{-1}	Equation
25% gluten	
192	$P = 14{,}609\tau^2 - 55{,}172\,\tau + 280{,}33$
290	$P = 5{,}8929\tau^2 - 9{,}3304x + 208{,}31$
385	$P = 29{,}562\tau + 135{,}44$
480	$P = 2{,}2098\tau^2 + 10{,}165x + 165{,}69$
27% gluten	
192	$P=-0{,}099\tau^4+1{,}1701x^3-0{,}5399x^2+0{,}0501x+152{,}39$
290	$P=1{,}8229\tau^2+7{,}0729x+125{,}32$
385	$P=-0{,}1447\tau^3+4{,}06x^2-7{,}3667x+139{,}9$
480	$P=4{,}2188\tau^2-6{,}0164x+150{,}85$

In first 2 minutes it was observed a relative stability of energy consumption, which presents that in this period the process is limited only at mixing raw materials, without essential colloidal changes.

Next, till the end of the process (sixth minute) because of the physical impact of the working tool – blade and the colloidal processes, the dough changes its viscosity and elasticity properties, causing an increased resistance of the working body tool movement, therefore a growth of energy consumption. In the mixing process, after particle got wet, the mechanical action helps them join in a mass, forming dough. If mixing of the formed dough continues, this step-by-step improves its rheological properties.

Both, rapid and slow mixing leads to a quality formed dough, but the energy consumption itself is distinct for different working tool speeds. These can be observed from curves.

Graphs in Figure 2(a) and 2(b) show the energy consumption change depending working body speed, at different periods of kneading process.

Graphs also show that the increase of the working speed from about 200 up to 400 min^{-1} does not cause a significant increase in energy consumption, and even, in some cases it decreases, while further speed increasing causes a significant increase of power.

So, it can be concluded that in order to increase the quality of dough`s sensorial properties, it is recommended a variation of working tool speed only up to 400 min^{-1}.

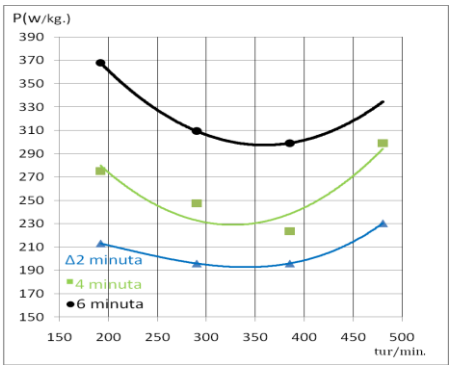

Figure 2(a) *Influence of working tool speeds on energy consumption for different periods of kneading process at 25% gluten content*

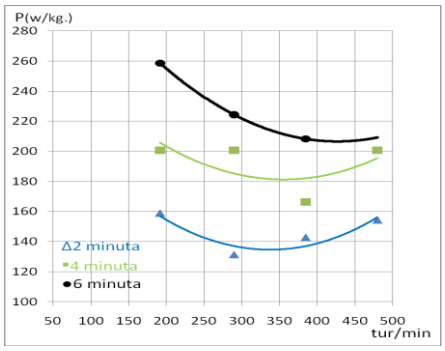

Figure 2(b) *Influence of working tool speeds on energy consumption for different periods of kneading process at 27% gluten content*

IV. Conclusions

The research showed the following results. During the homogenization of the mixture of flour, water and auxiliary products, energy consumption is minimal and relatively constant. Further, during kneading process, once the dough viscosity and elasticity change, energy consumption increases. This phenomenon is suitable for all studied working tool speeds.

Increase of the working speed from 200 to 400 min^{-1} does not cause changes in energy consumption, while further speed increasing is accompanied with increased energy consumption.

The use of high and low speed of working body tool in mixing process of preparation of the dough usually has the same aim and result as that of obtaining simply the dough, but in order to optimize the parameters which refer to energy consumption during mixing is needed to utilize necessary speed in accordance with dough viscosity and elasticity, namely the humidity that it contains.

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INVESTIGATION OF THE PROCESS OF LOW-TEMPERATURE HEAT TREATMENT OF SEMI-FINISHED BEEF WITH THE USE OF PRE-VACUUM PACKING

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Abstract. *A promising direction of development of the food industry is the development and introduction of innovative food processing technologies aimed at reducing process losses and maximize the preservation of the nutritional value of raw materials by heat cooking, increasing the shelf life of culinary products. For the object of research was considered beef. Found that the use of pre-vacuum packaging with subsequent low temperature heat treatment can improve bioavailability semi 12 - 14% and increase yield by 15 - 20%, compared with the conventional processing method.*

Keywords: animal raw materials, semi-finished product, vacuum packaging, hydrothermal treatment.

I. Introduction.

One of the important directions of development of food technology is the processing of raw materials at low to moderate temperature modes with pre-vacuum packed in heat-resistant polymer film known as Sous- Vide sockets technology to get food for the conservation of mass, food and biological value with an increase in shelf life [2, 3].

The object of research - beef - was portioning, with giving various geometric shapes: cube (0,7×0,7 cm), a large straw (1,5×0,5×0,5 cm) and beef (0,3 cm). Further beef was vacuum packed in plastic bags under vacuum gradient of 1,5 - 2,0% per second to achieve values of 97,0 – 99,9 % and subsequent heat treatment at temperatures of 333-373 K. The degree of the coolant culinary ready achievement is determined by characteristics for the product consistency and organoleptic characteristics. The moisture content of the coolant in the working chamber of the apparatus was maintained at 100 %. As control samples examined welded conventional manner. The degree of achievement of the determined readiness cooking desired consistency of the finished product, as well as its weight stabilized, indicating the completion of denaturation process animal protein component part.

The dependences of the change in mass of samples of beef on the length of Sous-Vide treatment at different water temperatures (shown only for the form - a cube) (Fig. 1).

Based on these relationships it can be noted that the process of weight loss for beef samples substantially depend on the shape and dimensions of the product due to increase in the specific mass transfer area per unit weight of the product while reducing the particle size of which varies as follows m^2/kg: for cubic – 0,14; for a large straw – 1,48; for stuffing – 2,78. It was found that the change of the samples depends on the beef slice, as well as operational parameters Sous-Vide treatment : from 12,0 (at 333 K) to 24,0 % (at 373 K) - for a cube, from 15,0 (at 333 K) to 27,5 % (at 373 K) - for a large straw, from 18,5 (at 333 K) to 30,5 % (at 373 K) - for stuffing. The decrease in the weight of the samples in the processing of beef in the traditional way is 31,0–35,0% for the experimental forms. By analyzing experimental data, it can be noted that the decrease in weight loss Sous-Vide processing speed due to a decrease in the loss of moisture in the tissue samples.

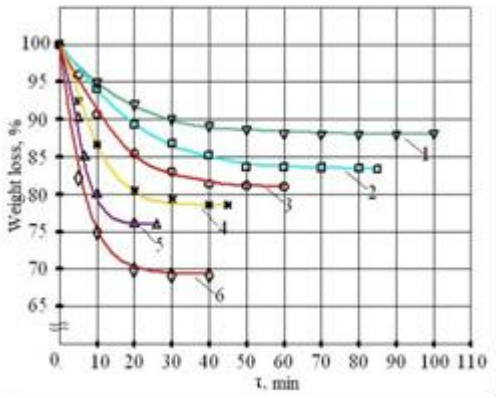

Fig. 1.*The dependence of the change in mass of samples vacuum-packed beef (cubed) on the duration of the heat of cooking at different temperatures: 1-333 K; 2-343 K; 3-353 K; 4-363 K; 5-373 K; 6- Treatment conventional manner*

Studies was established adiabatic dependence duration of the heat treatment of samples of beef from the temperature regimes. It is noted that an increase in temperature decreases the duration of the heat treatment (Fig. 2) from 100 to 25 minutes (333

K, 373 K) - for the cube and from 90 to 23 minutes (333 K, 373 K) - for large straw c 85 to 20 minutes (333 K, 373 K) - for stuffing.

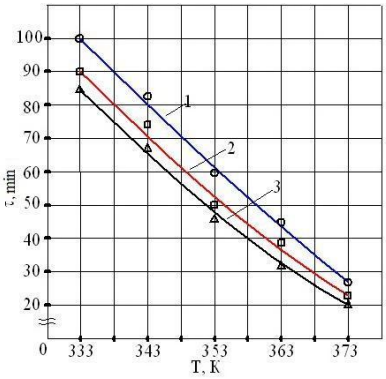

Fig. 2.*The dependence of the change in the duration of the heat of cooking vacuum-packed beef samples of temperature modes for different types of cutting: 1–block; 2-large straw; 3-minced*

During the study, it was also studied the variation degree of dehydration of the tissues of beef on the treatment temperature (Fig. 3), it is found that there are three stages of the process: heating, constant and decreasing rates of dehydration. It was established experimentally that the presence of the polymeric packaging characteristics of the working fluid in the chamber unit has a significant effect on the rate of dehydration of beef tissue samples, which varies in the range: 0,30 to 0,87 g/min (333 K, 373 K)

while the rate of the dehydration treatment in conventional manner beef is 1,76 g/min, 1,8...5,5 times higher.

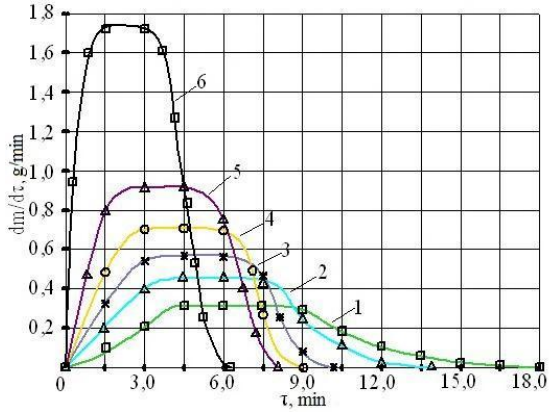

Fig. 3.*Dependence of the dehydration rate of vacuum packaged beef samples on the duration of the heat cooking at different temperatures: 1-333 K; 2-343 K; 3-353 K,;4-363 K,;5-373 K; 6-Treatment conventional manner*

By analyzing experimental data, it can be noted that the decrease in weight loss Sous-Vide processing speed due to a decrease in the loss of moisture in the tissue samples. In this pre-packaging results in a slight increase in duration of the heat treatment process semi-finished.

In the samples of beef were determined mass fraction of protein, fat, carbohydrates, vitamins, minerals, amino acid composition, the difference coefficient of amino acids, the biological value [1]. The experimental data presented in Table. 1.

Table 1.*Quality parameters of semi-finished beef*

Item	Sample not subjected to heat treatment	The traditional way	Using Sous-Vide processing temperature, K	
			333	373
Physical and chemical parameters				
Protein content,%	18,60	32,30	23,10	21,55
Fat,%	16,40	9,68	12,56	12,15
Acid number, mg KOH / g	1,95	0,82	1,30	0,96
Peroxide value,% J2	0,03	0,02	0,03	0,03
Vitamin B1 mg / kg	0,06	0,02	0,04	0,03
Vitamin B2 mg / kg	0,15	0,05	0,10	0,08
Vitamin PP mg / kg	4,7	2,1	3,4	2,9
Amino acid composition				
Isoleucine	5,10	3,30	3,85	3,62
Leucine	8,40	6,91	7,35	6,34
Lysine	8,10	8,42	8,08	7,86
Methionine + cystine	2,30	4,80	4,50	4,68
Phenylalanine + tyrosine	4,0	2,95	2,12	1,88
Threonine	4,0	3,78	3,75	3,81
Valine	5,56	4,10	4,72	4,51
Tryptophan	1,10	1,02	1,08	1,05
Indicators of biological value				
The coefficient of amino acid differences soon (RED),%	19,50	43,60	33,60	37,80
Biological value,%	80,50	56,40	66,40	62,20

Analyzing the data in Table 1, it can be noted that the vacuum packaged samples compared to control increases the mass fraction of the protein of 14-20%, of fat is reduced by 24-26% (at temperatures of 333-373 K), which is due to the different the value of process losses and marked better preservation of vitamins - 40-45 %.

It should also be noted that the use Sous-Vide treatment positively affects the performance bioavailability semi beef. Compared to the biological value of the vacuum packaged beef samples increases by 12-14% (at temperatures of 333-373 K).

Studies in beef samples studied changes in indicators of microbiological safety during storage at storage temperatures: T=276 and 298±2,0 K. In the samples studied in storage of aerobic and facultative anaerobic microorganisms, Escherihia coli, Staphylococcus aureus, Clostridium perfringens, and Listeria monocytogenes.

Found that the time to reach critical values of molds (cfu/g) depends on the temperature conditions of storage. Thus beef samples, storage temperature that was T=298 K±2,0, while achieving the microbiological contamination of critical values is two times less than for the samples with a storage temperature of T=276±2,0, respectively, 6 and 13 days. In the control samples during a critical value of microbiological contamination of 24 and 48 hours storage at temperatures T = 298 ± 2,0 and 276 K, respectively. During the test the shelf life of beef in the samples were found: Escherihia coli, Staphylococcus aureus, Clostridium perfringens, and Listeria monocytogenes.

Conclusions

Thus, it is proved that the samples which are subjected to beef Sous-Vide processing have high organoleptic properties, they are characterized by high biological value, increased vitamin content and they can be stored without special cooling 5 - 6 days, then there may be suitable for catering to special conditions (tourism, expeditions, etc.).

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THE CHANGES IN FATTY ACID AND TOCOPHEROL COMPOSITION OF FLAXSEED OIL DURING STORAGE

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Abstract. *Flaxseed oil is an important supplement, rich of linolenic acid. On the other hand the presence of linolenic acid causes easy oxidation of the oil. The fatty acid composition and tocopherol content are the indexes indicating stability of flaxseed oil as food stored in room temperature for long time. Results show that the content of linolenic acid is decreasing gradually as in the beginning its content is 51,7 % and in the end of the storage (180 days after storage) the content is 42,8 %. All stabilized flaxseed oils show the same trend as the control sample. The content of linolenic acid is decreasing gradually from 54,1% to 42,8 % and the content of oleic acid is increasing from 19,1 % to 27,4%.*

Key words: flaxseed oil, fatty acids, tocopherol, storage, oxidation

I. Introduction

Flaxseed oil is the richest source of polyunsaturated fatty acids, mainly linolenic (ω-3) and linoleic acid (ω-6). They have a health effect over Coronary heart disease and make the oil suitable as supplement (El-Beltagi *et al*., 2007; Huang and Milles, 1996; Huang and Zibon, 2001; Simopoulos, 2002; Martinchik *et al.*, 2012; Morris, 2007; Cunnane *et al*., 1992). Unsaturated fatty acids are the main components of triacylglycerols (85 %). Triacylglycerols, phospholipids, sterols and tocopherols are the most important biological active substances which determine food and therapeutic value of flaxseed oil.

On the other hand flaxseed oil has low oxidative stability and loses so fast his food value during the storage. The main changes in flaxseed oil during storage concern fatty acid and tocopherol composition. In this connection it is necessary to stabilize the flaxseed oil using different antioxidants for prolongation the time for its preservation.

The aim of this study is to find the changes in fatty acid and tocopherol composition of stabilized and unstabilized with different antioxidants flaxseed oil.

II. Materials and methods

All solvents and reagents were of analytical grade and were used without additional purification.

Antioxidants were provided by "Ikarov" Ltd.

Isolation of glyceride oil and determination of oil content. The oil was extracted with n-hexane **(ISO 659 2009)** in Soxhlet for 8 h.The solvent was partly removed in a rotary vacuum evaporator, the residue was transferred in pre-weight glass vessels and the rest of the solvent was removed under a stream of nitrogen.

Fatty acid composition. The fatty acid composition of triacylglycerols was determined by gas chromatography (CG) of fatty acid methyl esters (FAME) (ISO 5508 1990). FAME were prepared by pre-esterification with sulfuric acid in methanol as catalyst (Christie, 2003) and were purified by TLC on silica gel 60 G with mobile phase hexane:acetone = 100:8 (by volume). Determination was performed on a gas chromatograph equipped with a 60 m x 0.25 mm x 25 μm (I.D.) capillary DB-23 column (Hewlett Packard GmbH, Vienna, Austria) and a flame ionization detector. The column temperature was programmed from 130^{o}C (hold 1 min), at 6,5^{o}C/min to 170^{o}C, at 3^{o}C/min to 215^{o}C (hold 9 min), at 40^{o}C/min to 230^{o}C (hold 1 min); the injector temperature was 270^{o}C and detector temperature was 280^{o}C. Hydrogen was the carrier gas at a flow rate 0,8 ml/min; split was 50:1. Identification was performed by comparison of retention times with those of a standard mixture of fatty acid methyl esters subjected to GC under identical experimental conditions.

Tocopherols. High performance liquid chromatography (HPLC) (ISO 9936 2006) on a Merck-Hitachi (Merck, Darmstadt, Germany) instrument equipped with 250 mm x 4 mm Nucleosil Si 50-5 column (Merck, Darmstadt, Germany) and fluorescent detector Merck-Hitachi F 1000 was used for determination of tocopherol content and composition. The operating conditions were as follows: mobile phase of n-hexane: dioxan, 96 : 4 (by volume), flow rate 1 ml/min, excitation 295 nm, emission 330 nm. A 20 μl solution of crude oil (1.0%) was injected. Tocopherols were identified by comparing the retention times with those of authentic

individual pure tocopherols. The tocopherol content was calculated based on the tocopherol peak areas in the sample vs. tocopherol peak area of standard tocopherol solution.

III. Results and discussion

The period for investigation of stability of flaxseed oil is 180 days after storage (DAS).

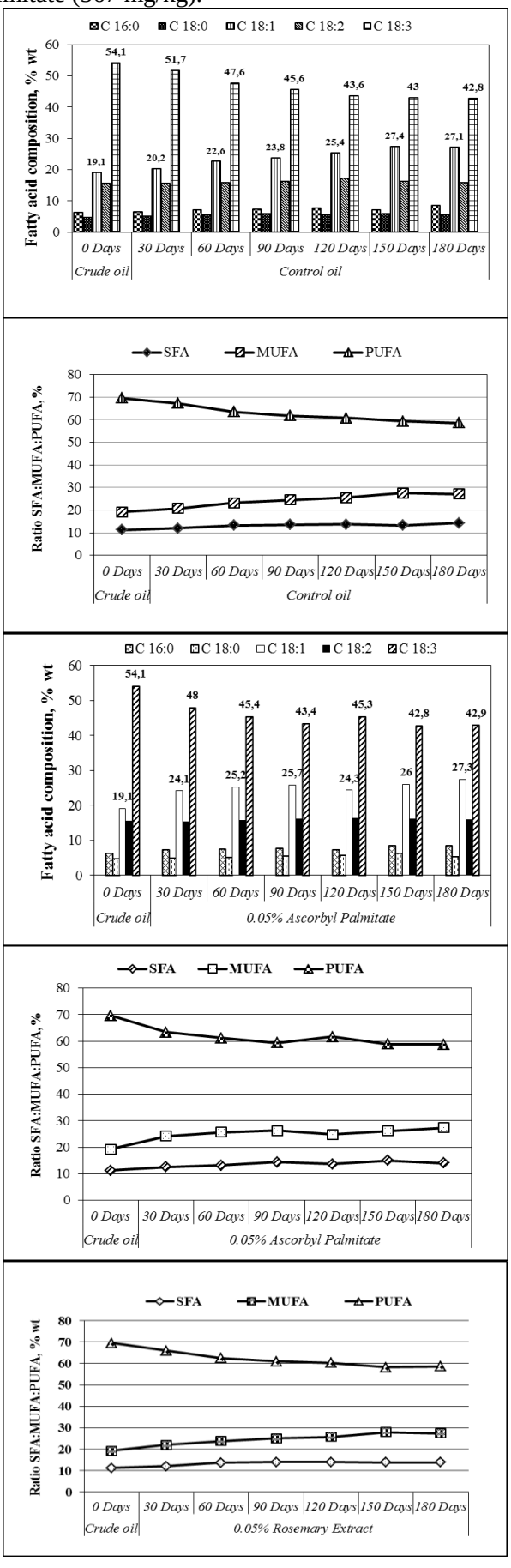
The changes in the fatty acid composition and the ratio saturated: monounsaturated: polyunsaturated fatty acids of flaxseed oil, stabilized with 0.05 % Ascorbyl Palmitate, 0,05 % Rosemary Extract and mixture of 0,025 % Ascorbyl Palmitate + 0,025 % Rosemary were studied (Fig.1).

The quantity of linolenic acid is decreasing gradually during the storage and in the last time the amount was found to be 42,8 %. The content of linoleic acid is almost constant during all the time of storage (15 – 17 %) while the content of oleic acid is increasing from 19,1 % to 27,1 %.

The data about flaxseed oil stabilized using 0.05 % Ascorbyl Palmitate are as follows: the trend is the same such as control oil – it was observed easy drop of content of linolenic acid and after 180 DAS the quantity is 42,9 %. In all investigated period the content of linoleic acid was about 15-16 %. The quantity of oleic acid gradually increased from 19.1 % in the beginning to 27,3% in the end of storage period. The content of linolenic acid of flaxseed oil stabilized with 0,05 % Rosemary extract is 42,6 % (180 DAS). There aren't changes of content of linolenic and linoleic acid compared with another two samples. The content of linolenic acid is 15 – 17 % and this of oleic acid is between 20 – 30 %. When it used a mixture of antioxidants 0,025 % Ascorbyl Palmitate and 0,025 % Rosemary Extract the content of linolenic acid has the highest level in the end of the storage period (44,5 %). The trand about linoleic and oleic acids didn't change.

The ratio saturated: monounsaturated: polyunsaturated fatty acids for all investigated oils during the storage is as follows: saturated fatty acids (11–16 %), monounsaturated fatty acids (9-28 %) and polyunsaturated fatty acids (55-70 %).

Tocopherols are an indicator for the stability and quality of flaxseed oil during the long storage. The total tocopherol content of control oil is ~700 mg/kg (Bozan and Temelli (2008), Gunstone (2002), Przybylski (2005). γ-Tocopherol is the main component of tocopherol fraction (more than 65.0 %). The individual tocopherol composition during the long storage doesn't change. The total tocopherol content is gradually decreasing and in the end of the storage the highest content of tocopherols was found to be in flaxseed oil stabilized with Ascorbyl Palmitate (567 mg/kg).



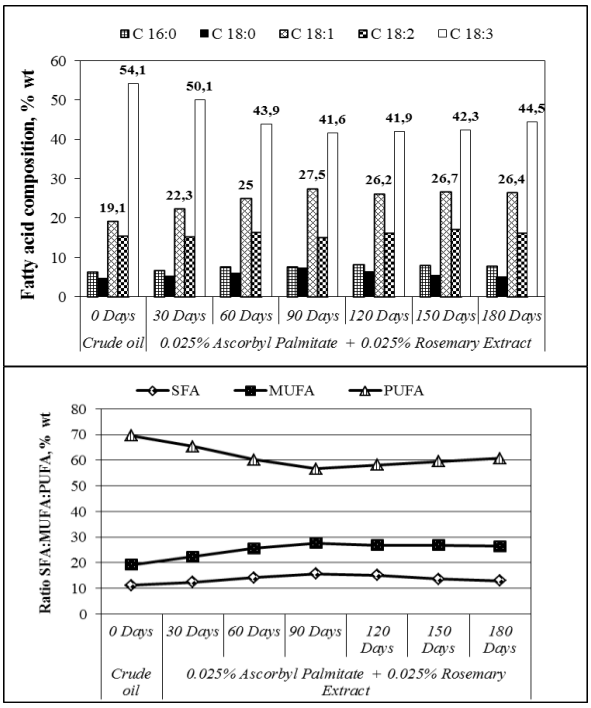


Figure 1. *The changes of fatty acid composition of flaxseed oil, stabilized with different antioxidants during the storage*

In the other oils tocopherol content is similar (~ 520 mg/kg). The trend for all oils is to decrease tocopherol content during long storage, as follows: 0,05 % Ascorbyl Palmitate from 700 mg/kg in the beginning to 567 mg/kg (180 DAS), 0,05 % Rosemary Extract from 690 mg/kg to 520 mg/kg, 0,025 % Ascorbyl Palmitate + 0,025 % Rosemary Exract from 700 mg/kg to 530 mg/kg and control oil from 700 mg/kg to 523 mg/kg, Fig.2.

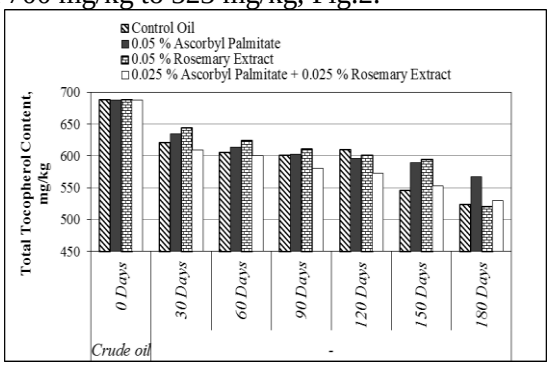


Figure 2. *The changes of tocopherols of flaxseed oil, stabilized with different antioxidants during the storage*

IV. Conclusion

During the long storage of crude flaxseed oil and flaxseed oil, stabilized with different antioxidant mixtures, it was established decreasing of content of the linolenic acid ($C_{18:3}$) and increasing content of the oleic acid ($C_{18:1}$). The total content of tocopherols was gradually decreased while the changes in individual tocopherol composition were not observed. The highest effect for stabilization of oil was established using Ascorbyl Palmitate – the lowest changes of fatty acid composition and tocopherols were found to be.

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UTILIZATION OF BY-PRODUCTS FROM FRUIT AND VEGETABLE PROCESSING: A REVIEW

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Abstract. *The food processing industry produced large quantity of waste by-products. It is established that one-third of the used product in fruit and vegetable processing being discarded which creates a significant environmental problem. This work provides an overview on recent research on utilization of fruit and vegetable processing by-products. Special attention was devoted to recent development of the recovery of biological active components and dietary fiber and its incorporation in different food. Additionally, some major challenges were identified and some selected major trends were discussed such as anaerobic digestion for buifuel production, composting and using as biosorbents of these by-products.*

Keywords: fruit, vegetable, by-products, waste, utilization.

I. Introduction

According to recent FAO reports a huge quantity of fruit and vegetable wastes and by-products from the fruit and vegetable processing industry are available throughout the world. For example fruit and vegetable processing, packaging, distribution and consumption in the organized sector in India, the Philippines, China and the USA generated a total of approximately 55 million tones of fruit and vegetable wastes. Nearly 50 % of all fruits and vegetables in the EU go to waste and during postharvest handling and processing 5.5 % of the fresh produce gets lost. The food loss and waste generated per capita in Europe is 280-300 kg/year. Amount the type of food, fruits (16,4 %) and vegetables (25,8 %) have the highest wastage rates of any food. [24, 37].

In this direction *Guvstavsson et al.* reported that roughly one-third of the edible parts of food produced for human consumption gets lost or wasted globally, which is about 1,3 billion tones per year [16].

Fruit and vegetable by-products are discharged as the remnants after the manufacturing of fruit and vegetable-based products. These remnants include peel, pips, skins, streams and cores. The waste portion in the processing of some fruits and vegetables can be large as 70 % of the harvested material. In leaf vegetables the external leaves are often removed as they are too hard and green and often have some defects. In celery only the stems, especially the whiter ones, are selected and the other parts constitute waste product. In onions, the residues are external membranes and sometimes scales. The peels are frequently wastes, as in the case of most fruits, potatoes, tomatoes, etc. In other cases the wastes are the fruit husks (banana, citrus, etc.) and shell (walnuts, etc.). The fruit stones are also wastes (peaches, apricots, etc.). After fruit processing for juice, wine and oil production, the press-cake constitutes a relevant waste (grapes, berries, olives, etc.). Currently all of these by-products are disposed of, on the principle end-use, usually at a cost to the producer, via animal feed, landfill or incineration. Thus, it potentially creates negative effect on the environment [26, 38].

It is recognized that fruit and vegetable by-products and wastes have however a high water content and are consequently perishable and microbiologically instable. This can result in environmental issues such as noxious odors or microbiological hazards. In addition, legislation is strongly encouraging industry to find new end-uses for these by-products [38].

Today, food wastes including fruit and vegetable by-products are considered as a cheap source of valuable components since the existent technologies allow the recovery of target compounds and their recycling inside food chain as functional additives in different products. For example, fruit stones and kernels are used for natural oils in the food industry, cosmetics and pharmaceuticals. Some vegetable peels have been shown to contain valuable phenolics and bioactive components. Some leafy-by-products are rich in dietary fiber, carbohydrates, antioxidants or prebiotics and etc. Fruit and vegetable by-products are rich in fermentescible sugars and they can be used as raw material for ethanol production [14, 38].

The aim of this work is to provide an overview on recent research on utilization of fruit and vegetable processing by-products with special attention to the recovery of biological active components and dietary fibers. Additionally, some major challenges to be

identified, and some selected major trends to be discussed.

II. Dietary fiber supplements

The concept of dietary fiber is well established and the nutritional benefits of dietary fiber intake are generally accepted. From a chemical point of view, dietary fiber consists of cellulose, hemicellulose, lignin, pectin, β-glucans and gums. The interest in foods rich in dietary fibers increased in the recent decades, and importance of this food constituent has led to the development of a large market for fiber-rich products and ingredients. The food processing industry produced large quantities of waste co-products. Over 1 million tones of vegetable trimmings from the vegetable processing industry are produced in the EU every year. They are inexpensive, available in large quantities, characterized by a high dietary fiber content resulting with high water binding capacity and relatively low enzyme digestible organic matter. A number of researchers had been used fruits and vegetable by-products as sources of dietary fiber supplements in retained food. For example, *Srojceska et al.* reported that incorporation of cauliflower trimmings into ready-to-eat expanded products significantly increased the dietary fiber level of proteins and water absorption index into the final product. Sensory test indicated that cauliflower could be incorporated up to the level of 10 % [33].

Vergana-Valencia et al. investigated unripe mango fruit as useful source for dietary fiber concentrate preparation. It was reported that mango dietary fiber maight be an alternative for development of products with balanced dietary fiber components and low glycemic response [36].

The upgrading potential of quince waste had been evaluated by *Pla et al.*, for production of fiber-rich powders with useful functional and physiological properties. The products obtained presented interesting hydration properties comparable to those reported from citrus and apple pulps. Authors concluded that these products could be finally applied for example in making functional meat and bakery foods [30].

In another study *Nawirska et al.* had been characterized dietary fiber fractions from apple, black current, choke berry, pear, cherry and carrot processing waste. They reported dietary fiber content between 54.2 and 98.8 % of dry matter (DM). The highest content was found in pear pomace (98.8 %) and in apple pomace (98.74 %) [22].

Due to its beneficial impact on the human health inulin as soluble dietary fiber is a desirable ingredient in many processed food and medical formulations. It can be used to replace sugar, fat and flour. Inulin had been obtained and characterized from Jerusalem artichoke (Helianthus tuberosus L.) [10, 27].

Another research had been carried out to evaluate some functional properties of fiber concentrates, from apple, orange, lemon and grapefruit residues. Authors concluded that all obtained fiber concentrates had a high content of dietary fiber between 44,2 and 89,2 g/100gDM, with a high proportion of insoluble dietary fiber. Every concentrate studied had interesting characteristics, suggesting possible applications (volume replacement, thickening or texturizing) in the development of foods, reduces in calories and rich in dietary fiber [13].

Fiber preparation could be used in food as flour substitutes in bread, cookies or pasta. They had also been added in soups, sauce, mayonnaise, jams, spreads, dairy products, drinks, processed meat and cakes. Enzymatic production of a soluble-fiber hydrolizate from carrot pomace and its sugar composition had been reported by *Yoon et al. Marin et al.* established by-products from different citrus processes as a source of customized functional fibers. *Sudha et al.* reported incorporation of ground apple pomace in wheat flour for producing of cakes with 14,2 % total dietary fiber and high acceptable quality. Incorporation of mango peel powder in wheat flour formulations for dietary fiber enriched biscuits and macaroni had been reported by *Ajila et al.* [2, 3, 21, 34, 40].

Table 1. *Dietary fiber (DF) content of some fruit and vegetable processing by-products (% in dry matter)*

Source of fiber	Total DF, % DM	Reference
Apple pomace	78,2-89,8	*Elleuch et al.*
Orange peel	64,3	*Elleuch et al.*
Grapefruit peel	44,2-62,6	*Elleuch et al.*
Lemon peel	60,1-68,3	*Elleuch et al.*
Mango DF concentrate	28,05	*Elleuch et al.*
Peach DF concentrate	30,7	*Elleuch et al.*
Mango peel	51,2	*Ajila et al.*
Cooked pear by-product	75,4	*Aguedo et al.*
Cooked apple by-product	69,0	*Aguedo et al.*
Grape pomace	77,9	*Waldrom K.*
Pea hulls	91,5	*Waldrom K.*

Aguedo et al. studied composition of by-products from cooked fruit processing and its potential use in food products. Recently *Elleuch et al.* described characteristics, technological functionality and commercial applications of dietary fiber and fiber

rich by-products. Authors concluded that the fiber rich by-products could fortify foods, increase their dietary fiber content and result in healthy products, low in calories, cholesterol and fat. They may also improve physical and structural properties of hydration, oil holding capacity, viscosity, texture, sensory characteristics and shelf-life [1, 11].

Table 1 presents dietary fiber content of some fruit and vegetable processing by-products.

III. Sources of nutraceuticals and functional food ingredients

Presently, producers are striving to create products which contain a value-added factor, such as dietary fiber or in more recent times, phytochemicals. The production and addition of such nutrients could be quite costly for the producer. In the fruit and vegetable processing around one-third of the used product being discarded. This could be costly for the manufacturer and also may have a negative impact on the environment. Many researchers had shown that these by-products could have a high nutritional value and they could be used as food ingredients due to their functional abilities. The main groups of plant secondary metabolites that are suitable for use in nutraceuticals or as functional food ingredients are terpenoids (lycopene, β-carotene, luteine, limonene, etc.), the polyphenols (flavonol, isoflavone, anthocyanin, phenolic acids, etc.) and organosulfur components (e.g. glucosinolates) [26, 38].

The processing of fruits and vegetables generates substantial quantities of phenolics-rich by-products which could be valuable natural sources of antioxidants. The possibility of recovering high amounts of phenolics with highest activity, economic justification and phenolic content had been obtained from apple, pear, tomato, golden rod and artichoke [29].

Balasundram et al. reviewed that the total phenolic content in peels of lemons, oranges and grapefruits were 15 % higher than thus in the peeled fruits. Peels from apples, peaches and pears contained twice the amount of total phenolics as found in the peeled fruits. Similarly, peels of yellow and white flesh nectarines contained at least twice as much phenolics as the flesh. Total phenolic content reported in seeds of several fruits, i.e. mango, longan, avocado, goope seed and skin, etc., were higher than that of the edible flesh. So, such seeds could be a valuable source of antioxidant phenolics. Another reported richer source of phenolics are tomato skin and seeds [5].

Another authors presented that the common plant phenolic antioxidants are tochopherols, flavonoids and related compounds like coumarins, cinamic acid derivatives and chalcones, phenolic diterpens and phenolic acids. The reported antioxidant content of some typical by-products was as follow: apple pomace (2,4 g/kgDM), orange peel (1,8 g/kgFM), lemon peel (1,9 g/kgFM), grapefruit peel (1,6 g/kgFM), potato peel (7,8 g/kgDM expressed as ferulic acid), red onion scale (105,5 g/kgDM as ferulic acid) and etc. [25].

Roldan et al. reported that processing and stabilizing onion wastes could solve the environmental problem derived from a great onion wastes disposal. Moreover, obtaining stabilized onion by-products as natural antioxidant food ingredients could be advantageous to food industry, not only to improve the use of onion wastes but also to obtain new natural and functional ingredients. In this study had been shown that processing of onion wastes to obtained a pasteurized paste were the best alternatives to obtain an interesting stabilized onion by-product with good antioxidant properties [31].

Ajila et al. reported that incorporation of 7,5 % mango peel powder into macaroni increased polyphenols content from 0,46 to 1,80 mg/g and carotenoid content from 5 to 84 μg/g of macaroni. It had been concluded that incorporation up to 5 % mango peel powder into the formulation of macaroni yielded an acceptable product with improved nutritional properties [2].

Carotenes (up to 2 g/kg dry matter) had been considered to be most valuable components to be recovered from the carrot pomace, while other major constituents were uronic acid, neutral sugars and fibers. Carotenoids could be extracted also from orange peel and tomato pomace [25].

Nikolova M. and Prokopov Ts. described the characteristics and functional properties of natural origin lycopene. It was reported that the peel fraction of tomato waste contains lycopene up to five times more than the pulp (on wet basis). They concluded that food processing by-products could be significant source of valuable bioactive components and natural color pigments. These products can be used as functional food and dietary supplements [23].

Toor et al. suggested that the skin and seed fraction of tomato were very rich source of antioxidant compounds hence the incorporation of the skin and seed fraction during processing could lead to about 40-53 % increase in the amount of all the major antioxidants in the final product [35].

In another study *Chantaro et al.* demonstrated the feasibility of using carrot peels to produced antioxidant dietary fiber which may be used as a food ingredient [9].

An effective fermentation with *Saccharomyces cerevisiae SL100* yeast cells of hydrolysates from Jerusalem artichoke tuber and stalk flours and pretreated mask had been achieved. The results from

this study showed that both artichoke substrates and additionally pea hulls could be used for effective ethanol fermentation [15].

Recently, detailed review had been presented by *O'Shea et al.* concerning nutritional and functional properties of the by-products of food processing and their potential applications as nutritional new ingredients in food. By-products from apple, grape, lemon, mango, orange, peach, carrot, cauliflower, onion and potato processing had been discussed [26].

IV. Biofuel production

Fruit and vegetable wastes contain 8-18 % of total initial solid and 87 % of total volatile solid (VS) which are suitable for anaerobic digestion as the organic portion also contains 75 % sugars and hemicellulose, 9 % cellulose and 5 % lignin, with a total of 75 % being biodegradable. However, in the bio-fuel production process through anaerobic digestion of fruits and vegetable wastes, because of the low cellulose content, intermediate products such as volatile fatty acids are formed during acidification, which in turn inhibit subsequent methanogenesis. Thus, the control of pH in raw materials becomes important [8, 19].

Bouallagui et al. described the energetic potential of fruit and vegetable wastes and examined the performance of several groups of anaerobic bioreactors used for anaerobic digestion of these wastes. They reported that continuous two-phase system appears as more highly efficient technologies for anaerobic digestion of fruit and vegetable wastes. Using a two-stage system involving a thermophilic liquefaction reactor and mesophilic anaerobic filter, over 95 % volatile solids were converted to methane at a volumetric loading rate of 5,65 gVS/l.d. The reported average methane production yield was about 420 l/kg added VS [8].

In another research *Bouallagui et al.* concluded that the most significant factor for enhanced fruit and vegetable anaerobic digestion performance is to improved organic nitrogen content provided by the additional wastes. Consequently, the occurrence of an imbalance between the different groups of anaerobic bacteria which may take place in unstable anaerobic digestion of fruit and vegetable wastes could be prevented [7].

Alvares and Liden reported that semi-continuous co-digestion of solid slaughterhouse waste, manure and fruit and vegetable wastes could yielded about 0,3 m^3/kgVS methane [4].

Khalid et al. published detailed review focused on the process of anaerobic digestion which is considered to be one of the most viable options for recycling the organic fraction of solid wastes. Authors provided a broad overview of the digestibility and energy production (biogas) yielded of a range of substrates and the digester configurations that achieve these yields. They reported that the recent literature indicates that anaerobic digestion could be an appealing option for converting raw solid organic wastes including fruit and vegetable into useful products such as biogas and other energy-rich components. Relative biogas production rates and methane yield from co-digestion of fruit and vegetable waste with abattoir wastewater were reported to be 2,53 l/d and 611 l/kgVS respectively. For potato waste co-digested with sugar beet waste co-substrate these data were 1,63 l/d and 689 l/kgVS [20].

For ensuring stability of the anaerobic digestion *Jiang et al.* proposed remedial measures which have to be introduced. These included alkali addition, feed interruption and mixing with a nitrogen-rich supplement. Maintaining a suitable carbon to nitrogen ratio is essential for sustainable digestion, with optimum in the range of 25-30. In case of unfavorable C/N ratio, studies suggested that co-digestion with other substrates that have complementary nutrient characteristics can improve process performance. Authors concluded that co-digestion with card packaging and cattle slurry as co-substrates proved to be an effective means of maintaining stable operating conditions [18].

Another study had shown that anaerobic co-digestion of fruit and vegetable waste and activated sludge with 30:70 ratios in sequencing bath reactor results 88 % biogas yield [17].

Table 2 presents ultimate methane yields of some fruit and vegetable wastes [39].

Table 2. *Ultimate methane yield of some fruit and vegetable wastes*

Feedstock	**Methane yield,** m^3/kgVS
Banana peel (Robusta variety)	0,277 ± 0,007
Lemon pressings	0,473 ± 0,011
Rotten tomato	0,298 ± 0,012
Mango (Neelum variety)	0,373 ± 0,012
Onion outer peel	0,400 ± 0,014
Cauliflower leaves	0,190 ± 0,009
Cauliflower stem	0,331 ± 0,013
Potato peel	0,267 ± 0,017
Garden pea pods (seeds removed)	0,390 ± 0,013
Carrot (leaves)	0,241 ± 0,008
Carrot (petiole)	0,309 ± 0,010

V. Composting

Composting is a biological process which reduces the volume and mass of solid organic wastes, while producing a safe, stabilized and nutrient enriched soil amendment. Food waste composting in a variety

of composting system has gained considerable attention in last decade.

Fruit and vegetable processing by-products/waste and waste generated from greenhouse crops, which represent a worldwide environmental problem, could be converted into a nutrient-enriched bio-fertilizer and used for agricultural purposes and land restoration. One of the modern techniques applied is vermicomposting. It is a process involving the biostabilization of organic wastes by the join action of earthworms and microorganism. It had proven to be a low-cost and rapid technique for the efficient management of vegetable waste.

Recently *Fernandez-Gomez et al.* assessed the efficiency of vermicomposting as a recycling management option for biotransforming tomato-fruit waste from greenhouses into organic nutrient-rich product available for agricultural purposes. The obtained end product had been chemically stable and enriched in nutrients, demonstrating that tomato wastes could be successfully vermicomposted into a valuable soil amendment [12].

VI. Biosorbents

Over the last decade fruit and vegetable wastes had also shown potential as an adsorbent, as it is contains a large amount of cellulose and other vital components such as hemicellulose, lignin, lipids, proteins, simple sugars, water, hydrocarbon and starch. The fruit waste such as citrus peel, papaya seed, passion fruit shell, pineapple stem, grape waste, banana peel, mango peel, mango seed kernel, peach and apricots stone, jackfruit peel, apple and persimmon waste, whereas the vegetable waste such as pumpkin seed hull, bean husk, garlic peel and broad bean peel can be used to absorb dyes and heavy metals such as Cr, Cu, Au, Pb, Co, Cd, Zn and Fe [19].

Schiewer and Patil reported removal of cadmium by fruit waste derived from several citrus fruits, apples and grapes. Citrus peels were identified as the most promising bio-sorbent due to high metal uptake in conjunction with physical stability [32].

Recently *Patel S.* presented a judicious and pragmatic review depicting the key advances in implementations of the fruit and vegetable wastes in pollution mitigation, the underlying mechanisms, major challenges and the future implementation. Authors concluded that the results of the numerous studies on adsorbent efficiency of fruit and vegetable wastes demonstrate that they apart from their wide availabilities are endowed with fast kinetics and appreciable adsorption capacities. These value-added products are promising alternatives to the costly conventional methods for eco-friendly remediation of wide spectrum of pollutants [28].

VII. Conclusions

The food processing industry produced large quantities of waste by-products. In the fruit and vegetable processing around one-third of the used product being discarded which creates a significant environmental problem. Presently, producers are striving to create products which contain a value added factor such as dietary fiber or phytochemicals. The results of this review clearly demonstrate the high nutritional value that many fruit and vegetable by-products possess. Extensive research has shown these by-products to be a high source of dietary fiber. Their use can impact functional benefits like gelling, thickening and water binding. The by-products can also possess phytochemicals such as terpenoids, polyphenols and etc. Many results from recent studies have shown the possibilities of the incorporation of these by-products in different food. The possibilities of recovering of high amount of valuable bioactive components and natural color pigments from the fruit and vegetable by-products have also demonstrated. Moreover, some major challenges of these by products utilization were identified such as anaerobic digestion for biofuel production, vermicomposting and potential use as biosorbents.

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SOME ASPECTS OF FORCE LOAD CELLS CARDBORD PACKAGING IN DURING ITS FORMATION

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Abstract. *Cardboard boxing are widely used for packaging products in various industries. Trend of the present stage of development packaging machinery its increase the productivity of machines based on the principle of modular construction. Performance of each module is closely related to the kinematic parameters of motion of its working groups. Increasing of velocity and acceleration of working groups increases the dynamic loads on the elements of the packaging. To ensure successful implementation of the packaging process requires that the sum of the static and dynamic loads on the elements in the boxing packaging does not exceed certain limits, in possible damage to the packaging or its individual elements. The questions of power tens on cardboard packaging elements in the process of shaping and correlations between geometric and kinematic parameters of working groups and static and dynamic forces which influence the boxing are opened in this article.*

Keywords: cardboard boxing, formation from folded flat.

I. Introduction

In modern packing technologies cardboard boxing are used as packaging consumer packaging in the shape of packs of different construction made from cardboard and as transport packaging in the shape of boxes and trays made from cardboard. The most complicated operation of packing process of products in cardboard packaging its operation of packing shaping with workpieces of various types. The shape is done by bending the elements of packing along the lines creasing workpieces - cutting or folded flat workpieces. Often as workpieces of packing folded flat workpiece are used. In the process of forming the elements of packaging are static and dynamic loads of the working groups of the packaging machine. This range of pressures should promote normal flow of processes of formation for the shortest period of time to maximize efficency of packaging machines. The magnitude of loads on individual elements of packing should not exceed certain limits in which the damage to packaging is possible, the loss of desired shape and size. Questions strength cardboard boxing is sufficiently studied and widely represented in publications, such as [1] and [2]. However , the study of power load cardboard boxing in the process of packing operations are considered insufficient, particularly when the maximum values of the kinematic parameters of working groups. Therefore, the actual task of research at the present stage of development of the packaging machine assignment is to study the dynamic processes of packaging, including cardboard boxing manufacturing processes of procurement, to maximize machine productivity while limiting the power load on packing elements and provide high quality packing.

II. Power load cardboard boxing elements in the process of formation from folded flat workpieces

Study of power load elements cardboard packing in its shaping of the workpiece folded flat efficiently conduct analytical methods by constructing a mathematical model of turning workpiece based on the resistance element bending deformation of packing along the lines creasing. Construction of mathematical models have been made on the assumption that the resistance bending deformations are evenly spread along the lines creasing and friction sliding motion and rest are equal and constant values. Fig.1. shows the individual steps of the process of forming of a cardboard packing from folded flat blanks.

During the process of forming on the elements cardboard boxing by force action by the working of packaging equipment. External active forces acting on the elements of packaging and work for the deformation of lines creasing, namely overcome internal resistance forces in bending lines creasing. The value of the internal forces of resistance is determined by the points arising in the scoring lines in their strains. The design of folded flat workpieces characterized by two types of crease lines-lines creasing unstrained (Fig. 2a) and pre-deformed scoring lines (Fig. 2b), which were formed during the manufacturing process of folded flat workpieces.

The value of the resistance of these types of lines bend significantly different. Thus, the resistance points unstrained lines scoring M_{W1} much higher than

the resistance points of deformed lines M_{W2} (Fig. 3). Moreover, with expansion of folded flat workpieces the value of the resistance depends on the angle of opening φ. Thus, the torque resistance unstrained lines creasing M_{W1} when you change the angle φ from $\varphi_0=0^0$ to from $\varphi_k=90^0$ to initially increases M_{W10} to $M_{W1\max}$ and after reaching the angle $\varphi=\varphi_c$ decreases sharply. This is explained with beginning of the expansion of the workpiece $\varphi_0=0^0$ when accompanied by elastic strain and unstrained lines creasing with increasing angle φ of internal resistance lines creasing growing. When the angle φ_c in the range from 25^0 to 35^0 is reached, break lines creasing happens and torque resistance M_{W1} decreases sharply.

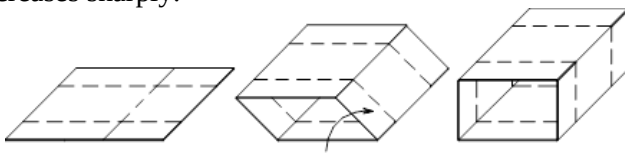

Figure 1. *The process of forming cardboard boxing from folded flat workpiece : a) folded flat workpiece; b) expansion of the workpiece ; c) disclosed cardboard boxing as a result of the process of formation .*

Figure 2. *Moments of the resistance bending lines creasing cardboard boxing: a) unstrained bend line; b) pre- deformed line.*

In turn, torque resistance when deformed lines M_{W2} with $\varphi_0=0^0$ is negative M_{W20}, that is actually active, the driving torque. The reason is that the pre-strain lines creasing the manufacture folded flat workpieces lines are formed in the deformed residual elastic force. This leads to a relaxation of deformed lines and some self-disclosure folded flat workpieces on these lines. Further increasing in angle opening φ moment M_{W2} slightly increases, but always remains smaller than the moment M_{W1}.

Thus, the task of forming cardboard boxing with folded flat folded workpieces is to overcome the working groups of packaging machinery moments of the resistance in the lines bend folded flat workpieces.

Fig 4. shows a diagram of power load elements cardboard boxing, when the process of forming implemented method of compression of folded flat workpiece diagonally and workpiece of boxing is between active working groups that moves in straight lines and fixed plane.

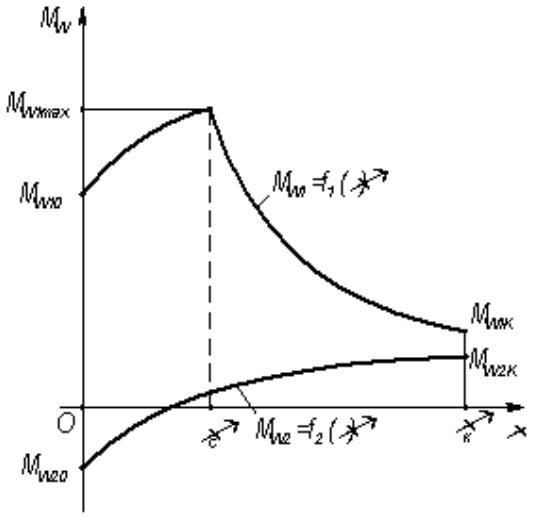

Figure 3. *The dependence of resistance points scoring lines M_{W1} and M_{W2} the angle φ opening folded flat workpieces cardboard boxing.*

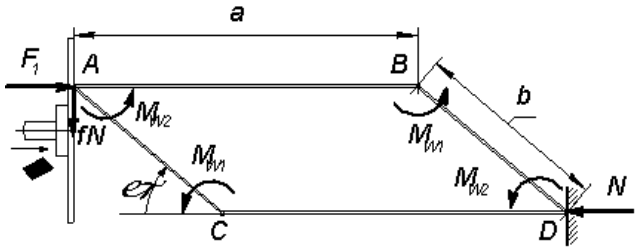

Figure 4. *Power load circuit elements cardboard packaging compression folded flat workpiece diagonally*

In this case the value of active force F_1 exerted by active working group of the cardboard packaging elements is determined by the dependence.

$$F_1 = 2\{(M_{W1} + M_{W2}) + \dot{\upsilon} \cdot b(m_1 \cos\varphi + ... \\ ... m_2 \sin\varphi) + b \sin\varphi \cdot (1 - f)\} \quad (1)$$

Where: $\dot{\upsilon}$ - acceleration which moves the active working group (first time derivative of velocity υ, b – the length of the short edge of container ; m_1, m_2 - mass, respectively, short and long edges of boxing; f - the coefficient of sliding friction element boxing on the surface of active working group.

With this method of forming the line AB through the top workpiece passed a very large load resistance is determined by the bend in lines B and D (Fig. 4). The magnitude of this pressure is determined by the following dependence.

$$F_C \begin{cases} M_{W1} + M_{W2} + \frac{\dot{\upsilon} \cdot b}{2}(m_1 \cos\varphi + ... \\ ...m_2 \sin\varphi)...m_2 \sin\varphi) \cdot b \cdot \sin\varphi \end{cases} \quad (2)$$

Maximum tens that can be passed through the upper line AB, is limited with longitudinal stability facets and its magnitude is given by Euler, namely

$$F_{C\max} = \frac{\pi^2 E \cdot l \cdot \delta^3}{12a^2} \quad , \quad (3)$$

where: E - modulus of cardboard ; l - length of the edge of the workpiece through the bend δ- thick workpiece of cardboard ; a - length of the face through the application of force by the active working group.

Present constraints [3] allows the maximum acceleration $\dot{\upsilon}_{\max}$ of the active working group in which is possible to transmit effort required for bending the workpiece along the lines creasing B and D.

$$\dot{\upsilon}_{\max} = \frac{\pi^2 E \cdot l \cdot \delta^3 b \cdot \sin\varphi - 12a^2(M_{W1} + M_{W2})}{6a^2 b \cdot (m_1 \cos\varphi + m_2 \sin\varphi)} \quad . \quad (4)$$

In excess of the reduced acceleration upper bound AB loses longitudinal stability and destroyed, making it impossible to further the process of forming. Thus, the acceleration $\dot{\upsilon}_{\max}$ determines the maximum speed of the active working group and sets the maximum performance of this method of forming cardboard boxing.

When forming cardboard boxing with folded flat workpiece exercise by capturing the front edge of the workpiece, then this method of packaging elements will not be loaded squeezing effort that eliminates the loss of longitudinal stability and fracture faces of the workpiece. Kinematic parameters of active working groups in this case has much lower limit and maximum efficency of this method is much higher than the productivity of the method of formation is discussed above .

Fig. 5 shows a diagram of forming cardboard boxing with flat- folded workpiece way to capture the front edge and motion capture in the circular trajectory. In this case, the line enjoys short workpiece.

With this method of forming necessary effort that must develop capture by dependence:

$$F_2 = \begin{matrix} 2(M_{W1} + M_{W2}) + 2m_1 b^2 \varepsilon + ... \\ ...m_2 b^2 \sin\varphi \cdot (\omega^2 \cos\varphi + \varepsilon \sin\varphi) \cdot k \end{matrix} \quad (5)$$

Where ω - angular velocity of capturing in the circular trajectory; ε - angular acceleration of capture; k - coordinate the application of the driving force of the gripper to the front edge of the workpiece.

In this case, the most loaded element is a workpiece front short line, under the range of external and internal loads that cause bending deformation of the front face. The value of the maximum strain dependence edge is determined

$$y_{\max} = \frac{4F_2(b-k)}{3\sqrt{3} \cdot E \cdot l \cdot \delta^3} \times ... \\ ... \times \frac{(b^2 - (b-k)^2)^{3/2}}{b} \quad (6)$$

A second option of forming cardboard boxing with blanks workpiece flat way to capture the front face is a way of straight motion capture (Fig. 6). In this method enjoys a long line workpiece, and the time required driving force is created by the influence of the fixed guide surface for a short line workpiece. In the process of expansion lateral line short workpiece slides along the guide surface and the point of contact with the guide rail edge is shifted in the direction from point A to point C, is the moment arm with force N decreases. The value of the normal force N depends on the value of the resistance points for each instantaneous position of the workpiece is determined by the driving time required to realize the process of shaping boxing. The highest value of total points in the resistance is characterized by the position of the workpiece when the angle φ is between 25 to 35 degrees, that corresponds the maximum value of the moment M_{W1}.

For each instantaneous position of the workpiece value of the normal force N is determined by the dependence:

$$N = 2 \cdot \begin{matrix} M_{W1} + M_{W2} + m_1 b^2 \varepsilon_1 + ... \\ ... + m_2 b^2 \sin\varphi \cdot (\omega_1^2 \cos\varphi + ... \\ ... + \varepsilon_1 \sin\varphi) \cdot c \end{matrix} \quad (7)$$

Where ω_1 - the angular velocity of rotation of the workpiece faces short; ε_1 - short rotation angular acceleration of the workpiece edge; c - coordinate of the point of contact short edge of the guide rail surface.

The value of force is applied by the gripper to the front edge of the workpiece for each instantaneous position is determined by the formula:

$$F_3 = 2(\cos\phi + f\sin\phi)\cdot\Big[\ M_{W1} + M_{W2} + \ldots$$
$$\ldots + m_1 b^2\varepsilon_1 + m_2 b^2\sin\phi\cdot(\omega_1^{\ 2}\cos\phi + \ldots \qquad (8)$$
$$\ldots + \varepsilon_1\sin\phi\ \ / c\Big]$$

Delight in this case should also have sufficient lateral stiffness to compensate for the lateral force F_4 from the workpiece.

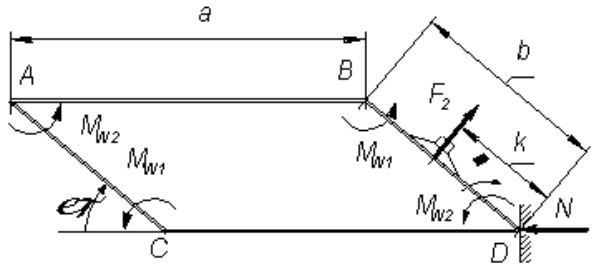

Figure 5. *Circuit power load items in cardboard packaging capture the front edge of boxing and motion capture in the circular trajectory*

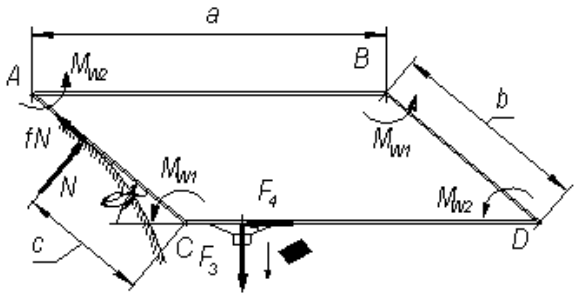

Figure 6. *Circuit of power load items in cardboard boxing capture the front edge of container and straight motion capture.*

It should be noted that some of the parameters of the process of formation, in particular, the value of the resistance points scoring lines in each case determined experimentally. The results of experimental studies, geometric, physical and mechanical properties of workpieces by applying formulas can objectively and accurately calculate parameters of reasonable job of packaging machine which realize the process of forming cardboard boxing from folded flat workpieces.

III. Conclusions

The studies make it possible to establish the basic laws of power load cardboard packaging elements of the business of packing machines for packing in the shaping of flat-folded workpieces:

- The greatest amount of stress on boxing elements corresponding position of the working machine in which the angle of disclosing container within $25^\circ \ldots 35^\circ$;
- Ways of forming of containers by capturing one of the faces of the workpiece grippers more rational and promising in terms of productivity than compression methods which works by folded flat workpieces diagonally, as they have less impact on the verge of power discloasing at maximum velocity and acceleration of business
- Key parameters that determine the amount of force on the cardboard boxing elements during its formation and thus limits the maximum kinematic parameters of working groups are the mechanical properties and thickness of cardboard δ, geometric dimensions and quality of the packaging lines creasing;
- To increase productivity through process of formation is to increase the elastic modulus E and cardboard increasing the thickness of cardboard δ, with increasing δ makes it possible to increase the load on the boxing elements is almost two orders of magnitude;
- Increasing the geometric dimensions of boxing accompanied by a decreasing in the maximum values of force on the boxing elements and leads to a significant decrease in productivity of the process of formation, including that increasing of lengths of sides a and b of boxing reduces the maximum efficiency of the process in almost in a stage.

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FUNCTIONAL FOODS BASED ON JERUSALEM ARTICHOKE

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Abstract. *The paper presents facts, as provided in the scientific literature, concerning the current tendencies in the manufacture of functional foods enriched with natural nutrients of plant origin. It focuses on the chemical composition of Jerusalem artichoke and its incorporation in healthy diets and nutrition therapy.*

Keywords: Jerusalem artichoke, functional foods

I. Introduction

Functional foods are among the latest developments in food science. A foodstuff can be regarded as functional if it has a beneficial effect on one or several bodily functions as a complement to normal eating habits, by means of which it contributes to general health and/or reduces the susceptibility to disease [16, 17].

As far back in time as the 1980s, the Japanese developed the concept of functional foods and defined them on the basis of their natural nutrient content [32]. Recent years have witnessed the application of various approaches to functional foods having to do with their production, the improvement of foodstuff composition in view of raising the nutritive value and the increase in biologically active substances in foods [18, 22]. Some approaches have concentrated on the regulation of the amount of specific components of plant origin whose content is affected by the manner and conditions under which the plant is cultivated. For instance, some authors reveal data testifying to the fact that soil fertilization accounts for changes in the presence of some chemical substances, such as vitamin C and zinc, in plants [29]. Due to the dynamic developments in the manufacture of low-calorie foods and beverages as well as of sweet sugar-free foods and beverages, sugar substitutes are widely used. From the point of view of food safety, polyols are preferred, e.g.: sorbitol, or other sugar substitutes of plant origin, such as agave syrup [21, 33]. The production of functional and healthy foods has profited significantly from the use of various unconventional plant raw materials, e.g.: sweet chestnut (Castanea sativa), Jerusalem artichoke (Helianthus tuberosus), etc. Gluten-free bread, bakery and confectionery products are extremely important to people suffering from coeliac disease or gluten enteropathy. In this respect, sweet chestnut flour is a very suitable alternative since it is not only gluten-free but it also has a beneficial chemical composition: it is low in fat, high in potassium, phosphorus, iron, vitamin C, B-complex vitamins, including folic acid, dietary fibre, etc. [25].

Jerusalem artichoke has been used for hundreds of years. Recently, the interest in Jerusalem artichoke has been growing steadily on the part of the food industry and cooking because the plant is rich in dietary fibre and its tubers are high in inulin, a prebiotic [2].

The focus of the present paper is on the summary and analysis of literature sources dealing with the chemical composition, healthy benefits and possibilities of using Jerusalem artichoke in functional food and beverage manufacture.

II. Biological and commercial importance of Jerusalem artichoke

Jerusalem artichoke (Helianthus tuberosus L.) is a herbaceous perennial tuber plant belonging to the Asteraceae family. The plant has a 3-4-metre tall shoot system above ground [28]. The tubers, its root system, are a major source of inulin, a polysaccharide [6]. Jerusalem artichoke has a number of important properties which make it a valuable plant with various applications: it is modest as regards soil, climate and cultivation; it can be planted in the spring and in the autumn, which allows for the rapid and dynamic growth of a big plantation; it gives good yield; the food industry can use the plant as a raw material in the manufacture of functional foods and beverages; it is an important raw material in the production of alcohol; it is also applied in phytotherapy and medicinal cosmetics; it paves the way for the production of cheap high-quality fodder and silage for farm animals [2]. Last but not least, Jerusalem artichoke is valuable as a honey plant. Bees use it in the late summer and autumn when flowering honey plants are scarce. Jerusalem artichoke honey has a golden yellow colour and a pleasant flavour recalling that of the sunflower [14].

III. Chemical composition of Jerusalem artichoke

Table 1 presents some data on the chemical composition of Jerusalem artichoke tubers.

Proteins. The protein content amounts to the average range of 1,6 – 2,4 g/100 g of fresh material [28]. Jerusalem artichoke contains all essential amino acids in a desirable ratio.

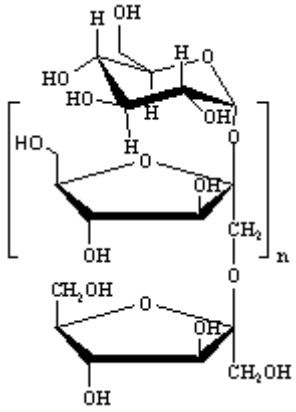
Table 1. *Chemical composition of Jerusalem artichoke tubers [2]*

Parameter	Content
Water, %	78
Energy, kcal	70
Protein, %	2,0
Fat, %	0,3
Total carbohydrate (in %), of which:	17,5
Inulin, %	12
Pectins, %	1,5
Cellulose, %	2,0
Hemicellulose, %	1,0
Mono- and oligosaccharides, %	1,0
Ash, mg/100g	1,2
Potassium, mg/100g	420
Sodium, mg/100g	3,2
Calcium, mg/100g	24,1
Magnesium, mg/100g	17,0
Phosphorus, mg/100g	75,0
Zinc, mg/100g	0,22
Chromium, µg/100g	7,4

The proteins in Jerusalem artichoke tubers are richer in lysine and methionine compared to the protein content of many other plants and the general opinion is that this is a high-quality protein which can be used for food and animal feed [24, 34].

Fat. The scarcity of fat in Jerusalem artichoke plants is attributed to trace amounts of mono- and polyunsaturated fatty acids whereas there are no saturated fats [36]. Polyunsaturated fatty acids – the presence of linoleic acid (18:2, n-6) and linolenic acid (18:3, n-3) - has been estimated in the following amounts: 24 mg and 36 mg/100 g, respectively, in raw tubers [26].

Carbohydrates. Jerusalem artichoke is high in carbohydrates. The major monosaccharides are fructose and glucose and the basic oligo- and polysaccharides are fructooligosaccharides, inulin, pectin, cellulose and hemicellulose [28]. The polyfructan inulin is a dominant component of Jerusalem artichoke tubers. It is a prebiotic substance belonging to the group of soluble dietary fibre [30]. As a result of its beneficial effect on the human organism, inulin is being increasingly incorporated into foods and the interest in its manufacture has grown considerably [7]. For industrial uses, inulin is usually extracted from chicory roots or Jerusalem artichoke tubers by means of hot water extraction followed by clarification and concentration of the liquor and spray-drying. In general, the inulin manufacture technology resembles the industrial extraction of sugar from sugar beet [3, 5]. From the point of view of chemistry, inulin is a linear polymer composed of D-fructose residues joined by (2→1)-glycosidic bonds. One end of the chain also contains α-D-glucose joined by a (1-2)-glycosidic bond [5, 15]:



Delchev et al. [4] point out that the flowers, leaves, and stems of Jerusalem artichoke plants contain the following sugars: glucose, fructose, galactose, mannose, arabinose, sucrose, kestose, and nystose. It is worth mentioning that the latter two oligosaccharides demonstrate a prebiotic effect comparable to that of inulin. Of all polysaccharides in Jerusalem artichoke flowers, the authors [ibid.] talk about the presence of pentosans (~ 6,78 % adm*), pectins (~ 10-11 % adm), cellulose (~ 21,08 % adm), polysaccharides which are difficult to hydrolyse (23,75 %) and polysaccharides that are easy to hydrolyse (17,54 % adm).

Other components. Jerusalem artichoke tubers contain large amounts of minerals as well as many

*adm – absolute dry matter

biologically active substances such as organic acids – 0,1 % [19], enzymes – inulinase (EC 3.2.1.7), inulosucrase (EC 2.4.1.9), polyphenol oxidase (EC 1.10.3.1), peroxidase (EC 1.11.1.7), etc. [2]. The aroma of the tubers that have not been heat-processed is mainly due to the sesquiterpene β-bisabolene and small amounts of saturated long-chain hydrocarbons.

Jerusalem artichoke tubers also contain heliangine (which regulates plant growth), spermine (a common component of plants participating in protein synthesis), 2,5-dihydrohybenzoic acid (with a bactericidal and antiviral effect), 4-xydroxybenzoic acid, caffeic acid, ferulic acid, chlorogenic acid, p-

coumaric acid and vanillic acid. Polyphenol compounds play a major role in tuber browning under technological processing [1, 28].

IV. Health effects of Jerusalem artichoke

The health effects of Jerusalem artichoke are due to the great variety of biologically active substances and, most of all, to the high amounts of dietary fibre. By definition, dietary fibre is not absorbed by digestion system organs [20]. Its physiological effect has to do with its physico-chemical properties. Dietary fibre increases the volume of food and leaves a feeling of satiety. It affects digestion, resorption and nutrient metabolism via water and bile acid absorption, gel formation, cation exchange, etc. Dietary fibre alters the assimilation of glucose, cholesterol, medicinal drugs and toxins and it also normalizes the intestinal microflora. Its breakdown leaves acidic by-products which protect the mucous membrane against malignant growth and help in the elimination of mutagenic substances and the free ammonia in the intestine, etc. [2, 11]. It is widely believed that insufficient dietary fibre intake contributes to an increased risk of many diseases, such as obesity, diabetes mellitus, gout, coronary heart disease, cholelithiasis, etc. [20].

The hypolipidemic function of various dietary fibres has been well documented. For instance, pectin substances possess a marked hypocholesterolemic effect attributable to their high sorption capacity. They contribute to the feeling of satiety and their normalizing effect on glucose tolerance is bigger compared to other types of dietary fibre. What is more, pectins have significant immunostimulating activity and their ability to bind metal ions and radioactive isotopes is used in protective job-oriented diets [10, 11, 12].

Inulin is a major representative of the dietary fibre in Jerusalem artichoke tubers. In addition to the above-mentioned physiological effects of dietary fibre, inulin can enhance the assimilation of some important minerals like calcium [35]. The absorption of this bioelement from food is accomplished by active transportation in the upper parts of the small intestine. With normal eating habits, about 30% of calcium is usually absorbed. In the large bowel, most of the calcium is in the form of insoluble complexes. Here, under the influence of the short-chain fatty acids produced in the intestinal fermentation of inulin, calcium solubility rises, which stimulates the assimilation of calcium via passive diffusion [5].

Phytotherapy utilizes Jerusalem artichoke in metabolism normalization in cases of obesity, some kidney diseases, in the improvement of the secretory and peristaltic functions of digestion system organs and especially of the bile secretion with patients suffering from atherosclerosis, diabetes mellitus, etc. [9, 13].

V. Application of Jerusalem artichoke in the manufacture of functional foods and beverages

In recent years, Jerusalem artichoke has been increasingly used in the food and flavour industry for the production of foods, beverages and food supplements. It has been used as a basic ingredient by various technologies and methods in the manufacture of inulin, fructose, glucose-fructose syrups, cellulose, ethyl alcohol, bakery and dairy products, canned food, drinks, etc. Owing to its beneficial effects on health, Jerusalem artichoke is also present on the market in the form of powder (flour) to be incorporated in cooked meals during their heat processing or in the form of tablets as a source of dietary fibre. The flowers and leaves of Jerusalem artichoke, alone or in combination with other medicinal plants, are used in the production of herbal tea and food supplements while the whole shoot system of the plant can serve as fodder for farm animals [2, 8, 9].

As a food ingredient, Jerusalem artichoke has the following effects:

- it enriches foods with dietary fibre (pectin, inulin, cellulose, etc.);
- it has a prebiotic effect (mainly due to inulin);
- it enriches foods with trace elements, vitamins and other biologically active substances;
- it improves the organoleptic parameters (taste, smell, consistency, etc.) of the product;
- it has a desirable effect on the functions of the human digestive system, the cardiovascular system and the urinary system due to its rich chemical composition and indisputable health effects.

Table 2 outlines the opportunities for the application of Jerusalem artichoke plants in the manufacture of healthy and functional foods.

Under the action of certain enzymes (inulinase, cellulase, etc.), the polysaccharides in *Helianthus tuberosus L.* are hydrolyzed to lower-molecular-weight sugars. The latter may ferment under the influence of some microorganisms, which is why Jerusalem artichoke turns out to be a valuable raw material in the production of bioethanol [23]. Research shows that the pre-processed and pre-hydrolyzed flours from Jerusalem artichoke tubers and stems are suitable for the alcohol fermentation brought about by *Saccharomyces cerevisiae*. Under the action of the microorganism, the fermentable sugars are completely used up within 24 h [27].

Table 2. *Jerusalem artichoke application in the manufacture of functional foods.*

Jerusalem artichoke	Application (usage)
Fresh tubers	Direct consumption, canned products, preparation of vegetable and meat-and-vegetable meals.
Tuber juice	Production of functional beverages, canned products, soups, sauces/dips, dressings, etc.
Mashed tubers	Canned functional food, cooked food, sauces/dips, dressings, dairy products, etc.
Tuber flour	Food supplements, bread and bakery products, cakes and confectionery, cereal foods, etc.
Flowers and leaves	Herbal tea, herbal extracts, food supplements, functional foods and beverages.

It should also be pointed out that the inulin isolated from Jerusalem artichoke finds great application in the manufacture of functional foods, beverages and other products based on this plant. Since most food products undergo heat processing in their production, it is also necessary to obtain information on the heat stability of the polysaccharide. Panchev et al. claim that the threshold of inulin heat stability is in the 152 - 158°C range [31].

VI. Conclusion

The paper presents data concerning the chemical composition and application of Jerusalem artichoke plants in the manufacture of functional foods. The analysis illustrates that the latter is extremely rich in dietary fibre and other biologically active substances, including the prebiotic inulin. The paper also outlines the beneficial physiological effects of Jerusalem artichoke and its dietary fibre which determine the usage of the plant in the production of healthy and functional foods and beverages.

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BIOSORPTION OF Fe(III) FROM AQUEOUS SOLUTION BY JERUSALEM ARTICHOKE (*HELIANTHUS TUBEROSUS L.*) POWDER

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Abstract. *Stalk powder of Jerusalem artichoke (Helianthus tuberosus L.) was tested for its ability to adsorb Fe (III) ions from aqueous solution. Kinetic and isotherm sorption experiments were carried out to evaluate the effects of contact time, pH, metal concentration and amount of the biosorbent. The maximum removal efficiency 84,0 % was reached at pH 7,0. The increases of initial concentration from 1,0 to 3,5 mg/l caused increasing of Fe (III) removal efficiency up to 33,7 %. When the mass of biosorbent was increased from 1,0 to 10,0 g the iron removal efficiency increased from 25,1 % to 83,5 %. It was found that the pseudo-second-order model provided the best fit for the experimental kinetic data. The type III (BET)-isotherm was obtained which is characteristic for multilayer type of adsorption.*

Keywords: biosorption, iron, removal, aqueous, solution, artichoke.

I. Introduction

Owing to rapid industrialization, water is exposed to numerous pollutions. Environmental pollution with industrial wastewaters contaminated with various metals has become one of the major ecological problems nowadays. The wastewaters that consist of heavy metals ought to be treated, because it will harm the ecosystems and public health. The main toxic metal ions hazardous to humans as well as other forms of life are Cr, Cu, Fe, Se, Co, Ni, Cd, Hg, As, Pb, Zn, etc. Heavy metals are non-biodegradable and causing various diseases and disorders. Particularly, iron overload may lead to debilitating and life-threatening problems such as poor growth, heart failure and diabetes [2].

The existing methods used for water purification and in particular for metals removal could be classified in three main groups such as physical, chemical and biological. These include filtration, chemical precipitation, ion exchange and electrochemical treatment, membrane technologies, adsorption on activated carbon, evaporation, etc. Continuous efforts are being made to develop improved and innovative methods of water treatment. Adsorption is one of the successful methods of physicochemical treatment process to remove heavy metals from aqueous solutions [16].

Recently there has been a tendency to shift conventional adsorbents with natural sorbents. There are many data in the literature for the ability of a large number of microbial and plant waste materials to bind heavy metals. Most of the adsorption studies focused on using plant wastes such as leaf powder, rice husk, sunflower stalks, peanut hull pellets, marine algae, etc. Different types of bacteria, mould and yeast have been also used [1, 3, 7, 9, 11, 12, 14, 15].

Natural sorbents are characterized by a number of advantages such as low price, large availability, high efficiency, the possibility for regeneration, biodegradability and safety [17].

Biosorption may be defined as a process of removing the metal or metalloid components from the aqueous solution by biological materials. The mechanisms involved in the process of biosorption include chemical sorption, complex formation, surface adsorption, inner porous adsorption, ion exchange, etc. It has been found that in the cellular and tissue materials exist a large number of groups (-COOH, -OH, -SH, =NH, $-NH_2$, etc.) which have ability to bind metal and therefore they are ionic functional groups of the biomass [6, 8].

Numerous empirical models for single solute systems have been employed to describe the biosorption equilibrium, namely Langmur, Freundlich, Brunauer-Emmet-Teller (BET), Sips, Dubinin-Radishkevich, Temkin and Toth models. In kinetic modeling, the pseudo-first and –second order equations are considered as the most celebrated models [5].

It has been established that unlike the mono-functional synthetic ion exchange resins, natural sorbents are often more efficient in the solution purification containing various types and amounts of metal ions [17].

Lately the use of economical waste-derived material from agricultural sectors has been highlighted in the literature for heavy metal removal from wastewater [2].

In our previous study were presented data for the characteristic and adsorption properties of the powder of Jerusalem artichoke with respect to the removal of Cu(II) ions from aqueous solution. Relatively high purification of the aqueous solution of these ions by obtaining sorbent was reported [4].

The aim of this work is to investigate biosorption of Fe(III) ions from aqueous solution by powder of Jerusalem artichoke.

II. Materials and methods

Biosorbent preparation

In the present study the powder obtained from stalks of Jerusalem artichoke by cutting, drying (40°C), milling and sieving (laboratory sieve 0,80 mm) was used. For the removal of certain interfering components (pigments, etc.) the plant material was extracted twice with distillated water (1:7) for 45 min at 25°C under continuously stirring. After that the material was dried at 40°C.

Preparation of iron solution

Stock solution of Fe (III) was prepared by dissolving of $FeCl_3.6H_2O$ in distillated water. This solution was diluted with distillated water to obtain desired concentrations of working solutions for the batch experiments study.

Biosorption batch experiments

The pH value of the samples was adjusted by adding 0,1 M NaOH or HCl solutions. All chemical reagents used in the experiments were of analytical grade. Biosorption experiments were carried out in 250 ml Erlenmeyer glass flasks with 100 ml volume of iron solution. Batch experiments were conducted by varying the pH value (5, 6, 7, 8), initial iron (III) concentration (from 1,0 to 4,3 mg/l) and amount of biosorbent (from 0,5 to 10 g). Experiments were carried out at contact time of 24 h in order to reach equilibrium, agitation speed 100 rpm and ambient temperature t = 20,0±0,5°C. To distinguish between possible metal precipitation and actual metal sorption controls were used without biosorbent. All experiments were performed in duplicate.

Analytical methods

For determination of Fe(III) concentration in the solutions before and after biosorption, 10 ml of samples were withdrawn, filtered and filtrate was analyzed using NOVA-60 (Merck KGaA, Germany) Spectrophotometer at the 565 nm wavelength via complex formation with triazine derivative.

The metal uptake q (mg/g) was determined by employing the mass balance. If C_0 and C_e are the initial and final metal concentration (mg/l), respectively; V (L) is the initial volume of iron solution and m (g) is the mass of biosorbent material, the equilibrium metal uptake q_e (mg/g) can be calculated as:

$$q_e = \frac{(C_0 - C_e).V}{m} \quad (1)$$

The performance of biosorption was evaluated in terms of its removal efficiency as RE (%), estimated by the following equation:

$$RE = \frac{(C_0 - C_t)}{C_0}.100 \quad (2)$$

where: C_t is the iron (III) concentration at time t.

Kinetic experiments

Batch kinetic experiments were carried out. For this purpose, 2,5 g of biosorbent were contacted with 250 ml of iron (III) aqueous solution with initial metal concentration 4,3 mg/l in 500 ml Erlenmeyer glass flasks on a magnetic stirrer at 100 rpm. The effects of two pH values pH 3,5 (as initial pH value of the iron solution) and pH 7,0 were studied. At different time intervals ranging from 10 to 240 min the concentrations of iron (III) in the treated solutions were determined as described in analytical methods.

Kinetic modeling

The Lagergren model was employed due to its simplicity and good fit. Two different kinetic models were used to model experimental data.

The pseudo-first-order model is expressed as:

$$\frac{dq}{dt} = K_{1,ads}(q_e - q) \quad (3)$$

where: q_e (mg/g) and q are amounts of adsorbed metal ions on the biosorbent at the equilibrium and any time t, respectively; and $K_{1,ads}$ is the Lagergren rate constant of the first-order biosorption (min^{-1}). The model is based on the assumption that the rate is proportional to the number of free site. Integrating Eq. (3) between the limits, $t=0$ to $t=t$ and $q=0$ to $q=q$ yields the linearized version of this model:

$$\log(q_e - q) = \log q_e - \frac{K_{1,ads}.t}{2.303} \quad (4)$$

Linear plots of $log(q_e-q)$ versus t were plotted to evaluate this kinetic model and to determine rate constant and q_e from the slope and intercept, respectively.

The pseudo-second-order model is based on the assumption that biosorption follows a second-order mechanism, whereby the rate of sorption is proportional to the squire of the number of unoccupied sites:

$$\frac{dq}{dt} = K_{2,ads}(q_e - q)^2 \quad (5)$$

where: $K_{2,ads}$ is the rate constant of second-order biosorption (g/mg.min). Integrating Eq. (5) from $t=0$ to $t=t$ and $q=0$ to $q=q$ and linearization yields:

$$\frac{t}{q} = \frac{1}{K_{2,ads} \cdot q_e^2} + \frac{t}{q_e} \quad (6)$$

The parameters q_e and $K_{2,ads}$ are calculated from the slope and the intercept of the plot t/q versus t. It is not necessary to independently determine q_e to apply this model.

To determine the model fit, mean squired errors (MSE) were calculated by taking squire of the difference between experimental metal uptake data (q) and corresponding model predictions of the uptake (q_m) and dividing the sum of those squired errors by the number of data points (p) to reach data set:

$$MSE = \frac{\sum_1^p (q - q_m)^2}{p} \quad (7)$$

Isotherm experiments

Equilibrium sorption experiments were performed as follow. Biosorbent (0.5 g) were exposed to 100 ml iron (III) solution with an initial concentrations from 1.0 to 3.5 mg/l at constant pH 7.0±0.2, agitation time 100 rpm, ambient temperature t = 20.0±0.5°C for 24 h in order to rich equilibrium. Sorption isotherm is plotted of the sorbate uptake (q_e) versus the equilibrium concentration of the residual sorbate remaining in the solution (C_e).

III. Results and discussion

Influence of pH

Hydrogen ion concentration (pH) of the aqueous solutions is an important parameter since it affects the surface charge of sorbent and the degree of speciation and ionization of sorbent during adsorption [2].

The effect of pH on the Fe (III) removal from the aqueous solution by studied biosorbent is illustrated in Fig.1.

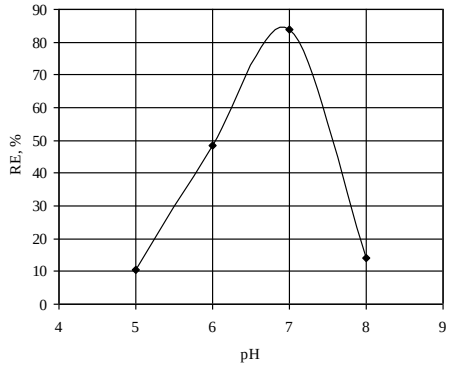

Figure 1. *Effect of pH on the removal of Fe (III) from aqueous solution by powder of Jerusalem artichoke*

It was shown that the maximum removal efficiency (84,0 %) was reached at pH 7,0. Similar result was obtained by *Dahlan et al.* [2] who reported that higher metal ions (Fe^{2+}) adsorption was obtained at higher pH (6-10) using sorbent prepared from siliceous waste. *Shokoohi et al.* [13] carried out similar biosorption experiments at pH 7,0 for iron removal from aqueous solution by biomass of activated sludge.

Influence of initial iron concentration

The effect of initial concentration on removal of Fe (III) from aqueous solution by used biosorbent was studied by varying the initial iron concentration from 1,0 mg/l to 4,0 mg/l. Batch experiments were carried out with 0,5 g biosorbent at pH 7,0±0,2. The obtained results are presented in table 1.

It was found that Fe (III) removal increased with increased initial iron concentration from 1,0 to 3,5. This can be explained by the surface area and the availability of high adsorption sites. This might be due to the increase in driving force of the iron concentration gradient [2].

Table 1. *Effect of initial concentration on Fe (III) removal from aqueous solution by powder of Jerusalem artichoke*

Initial iron concentration, mg/l	**Final iron concentration**, mg/l	q_e, mg/g	**RE**, %
1,0	0,78	0,044	22,0
2,0	1,53	0,094	23,5
2,5	1,90	0,120	24,0
3,0	2,14	0,172	28,7
3,5	2,32	0,236	33,7
4,0	3,30	0,140	17,5

As the concentration reached 4.0 mg/l the iron removal started to decrease may be due to limited or saturated available adsorption sites.

Influence of contact time

Equilibrium time is another important operational parameter for the effectiveness of biosorption process. This time represents the contact time where the active site and the sorbate are in contact to each other for adsorption to occure. The effect of the contact time was studied by using 2,5 g biosorbent in 250 ml aqueous solution with 4,3 mg/l initial Fe (III) concentration at pH 7,0±0,2. Results are presented in table 2. It was found that increasing of the contact time from 10 min to 210 min caused iron removal efficiency improvement from 23,5 % to 47,2 %. Beyond 210 min of equilibrium time, there is no further significant Fe (III) removal observed. Similar trend results were reported by *Chandrakala et al.* [1], *Dahlan et al.* [2] and *Shokoohi et al.* [13].

Influence of the amount of biosorbent

The effect of the amount of biosorbent on iron (III) removal from aqueous solution by flour of Jerusalem artichoke is shown in Fig. 2. Batch experiments were carried out by varying the biosorbent amount from 1,0 g to 10,0 g at pH 7,0±0,2.

When the mass of biosorbent was increased from 1,0 g to 10,0 g the iron (III) removal efficiency increased from 25,1 % to 83,5 %.

Table 2. *Effect of contact time on Fe (III) removal from aqueous solution by powder of Jerusalem artichoke*

Contact time, min	**Final iron concentration**, mg/l	**q_e**, mg/g	**RE**, %
10	3,29	0,101	23,5
30	2,91	0,139	32,3
60	2,75	0,155	36,0
90	2,59	0,171	39,8
120	2,48	0,182	42,3
180	2,30	0,200	46,5
210	2,27	0,203	47,2
240	2,27	0,203	47,2

This happens due to greater availability of the surface area of the sorbent. Similar results have been found from other researchers [1, 2, 10, 13].

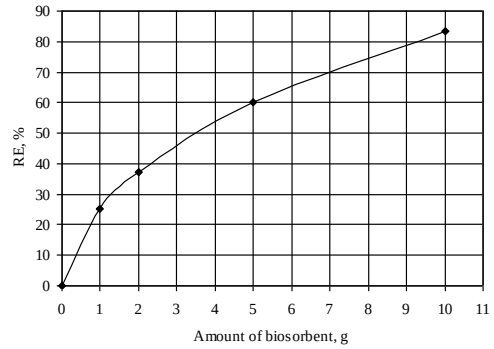

Figure 2. *Effect of biosorbent amount on the removal of Fe (III) from aqueous solution by powder of Jerusalem artichoke*

Kinetics

Kinetics of metal binding at two pH values is depicted in Fig. 3. The equilibration time at pH 7,0 was approximately 210 min and at pH 3,5 it was 90 min. At pH 7,0 the equilibrium uptake was approximately 2 times higher than at pH 3,5. This is a typical phenomenon in biosorption. Metal binding is usually higher at higher pH due to reduced competition by protons for the same binding sites [12].

A linearized plot for the first-order Lagergren model is shown in Fig. 4.

The first-order rate constant (K1,ads, min-1) and qe were determined and values are presented in table 3. It was established that this model failed to provide a realistic estimate qe since the experimental values of qe were much higher than the fitted values for both pH studied.

The linearized second-order plot is shown in Fig. 5. The determined values of qe and rate constant (K2,ads, g/mg.min) are presented in table 3. The results shown, that the pseudo-second-order kinetic provided the best fit for the kinetic data.

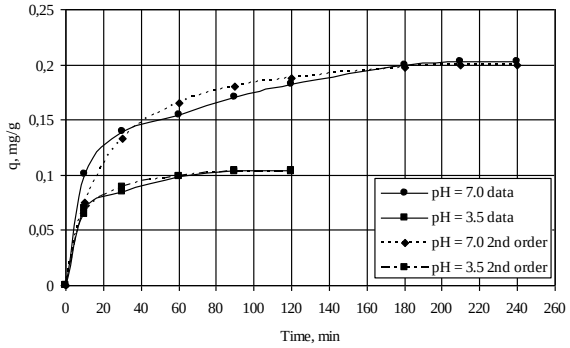

Figure 3. *Kinetics of Fe (III) binding by powder of Jerusalem artichoke. Experimental data and predictions of the second-order model*

The corresponding metal uptake at different time intervals was calculated for the second-order model and plotted in Fig. 3.

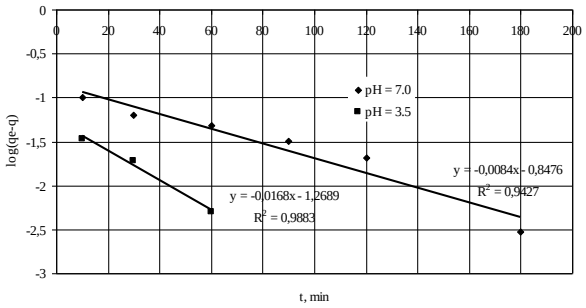

Figure 4. *Linearization of Fe (III) binding kinetics from Fig. 3 according to the first-order Lagergren model*

The modelling error (MSE) was almost negligible for the second-order kinetic model contrary to first-order model (table 3).

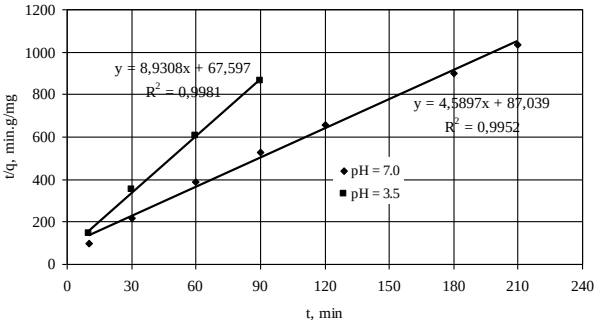

Figure 5. *Linearization of Fe (III) binding kinetics from Fig. 3 according to the second-order model*

Sorption isotherm

The relationship between equilibrium uptake (q_e) and equilibrium concentration of Fe (III) was plotted as sorption isotherm in Fig. 6. The obtained sorption isotherm seems to be type III (BET)-isotherm which is characteristic for multilayer type of adsorption. However, more research is need for isotherm modeling.

Table 3. *Rate constants and equilibrium metal uptake at pH 3.5 and pH 7.0 for Fe (III) binding by powder of Jerusalem artichoke*

Parameters	First-order kinetics		Second-order kinetics	
	pH 3,5	pH 7,0	pH 3,5	pH 7,0
$K_{i,ads}$	0,04	0,02	1,18	0,24
q_e Mod., mg/g	0,05	0,14	0,112	0,218
q_e Exp., mg/g	0,104	0,203	0,104	0,203
R^2	0,9883	0,9427	0,9981	0,9952
MSE	0,003	0,005	1.10^{-5}	1.10^{-4}

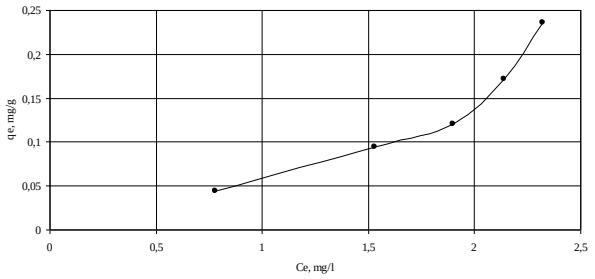

Figure 6. *Ecuilibrium sorption isotherm of Jerusalem artichoke powder*

IV. Conclusions

In this study, the ability of stalk powder from Jerusalem artichoke (*Hellianthus tuberosus L.)* to bind Fe (III) in aqueous solution was investigated and the results were compared with other published data. Biosorption is moreover influenced by various parameters such as initial pH, initial metal concentration, contact time and amount of biosorbent. The maximum removal efficiency 84.0 % was reached at pH 7.0. The increase of initial concentration from 1.0 to 3.5 mg/l caused increasing of Fe (III) removal efficiency up to 33.7 %. When the mass of biosorbent was increased from 1.0 to 10.0 g the iron removal efficiency increased from 25.1 % to 83.5 %. It was found that the pseudo-second-order model provided the best fit for the experimental kinetic data for two studied pH values 3.5 and 7.0 with correlation coefficients $R^2 = 0.9981$ and $R^2 = 0.9952$, respectively. The modeling error was almost negligible. The type III (BET)-isotherm was obtained which is characteristic for multilayer type of adsorption. However, more detailed studies are needed to clarify the Fe (III) biosorption mechanism by powder of Jerusalem artichoke.

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PEA PROBIOTIC FOODS AND BEVERAGES DURING STORAGE

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Abstract. *Non-traditional functional foods and beverages (pea yoghurts and beverages) with probiotic microorganisms were obtained. Pea yogurts and pea acidophilic beverages had a high concentration of viable cells (over 10^9cfu/cm^3) and moderate titratable acidity. The changes in the concentration of viable cells and in the titratable acidity of the pea yoghurts and beverages during storage at 4±2°C for 20 days were monitored. It was shown that during storage there are slight changes in the pea products but they can be stored at 4±2°C and consumed as probiotic yoghurts and beverages up to the 20th day of storage.*

Keywords: pea milk, starter, *Lactobacillus*, non-traditional food and beverage

I. Introduction

According to The European Commission's Concerted Action on Functional Food Science in Europe (FuFoSE), coordinated by International Life Science Institute (ILSI) Europe a functional food is a food that together with its basic nutritional impact it has beneficial effects on one or more functions of the human organism thus either improving the general and physical conditions and / or decreasing the risk of the evolution of diseases.

Along with the basic necessary nutrients for the organism, functional foods contain ingredients that contribute to the improvement of the health of the consumer. The group of functional foods includes probiotic preparations and products containing a high concentration of viable cells of microorganism promoting human health.

Generally, probiotic bacteria are used in the preparation of yoghurts and other fermented lactic acid beverages [3, 8]. Usually, probiotic micro-organisms are of human or animal origin, but among them there are probiotic strains able to grow in non-dairy substrates [9]. Nowadays, the application of non-milk-based probiotic preparations used to obtain beverages or directly as probiotic tablets, capsules or lyophilized preparations increases (Multibionta, Enterogermina, Florastar) [9].

For their development lactobacilli require fermentable carbohydrates, amino acids, B-group vitamins, mineral elements, nucleotides [4]. Therefore, cereal crops as substrates for beneficial microorganisms allow obtaining various non-dairy fermented probiotic foods.

Probiotic bacteria and yeasts are included in the composition of many fermented cereal foods. Relationships occur between the two groups of microorganisms and they are associated with the formation of metabolites by one of the microorganisms that stimulate or suppress the growth of other microorganism. Co-cultured microorganisms compete for nutrients and produce substances that inhibit the growth of other microorganisms. On the other hand, yeasts form B-group vitamins which in turn enhance the growth of lactobacilli [7].

Currently, probiotic foods are mostly based on milk which causes some inconvenience due to the high content of lactose and cholesterol in it [5]. The latest developments of technology allow changing some of the structural characteristics of fruit and vegetables substrates by modification of the food components [2], making them ideal substrates for the cultivation of probiotic microorganisms, as they contain nutrients such as minerals elements, vitamins, fibers, antioxidants. At the same time in fruit and vegetable substrates there are no dairy allergens that would otherwise restrict the consummation of milk from certain population groups [6]. An additional problem is the increasing cost of animal breeding. All these reasons necessitate the search for new ways to develop functional foods.

Boza is a specific cereal-based product with high energy content and original taste. It also contains the necessary and characteristic cereal vitamins, mainly B-group vitamins, partially hydrolysed carbohydrates typical for wheat, oats, barley, maize and millet, and in some countries rice as well. Natural boza obtained from autoclaved thermally

hydrolysed wheat, rye and other cereals is a relatively perishable product that undergoes natural microbiological and physico-chemical changes.

Pea beans contain carbohydrates, dietary fibers, lipids, small amounts of saturated fatty acids, but mostly starch and valuable vegetable protein, as well as vitamins such as β-carotene, vitamins A, E, H, PP, B-group vitamins, vitamin C (in a raw state), mineral elements such as iron, zinc, copper, manganese, aluminum, boron, molybdenum, fluorine, vanadium, nickel, titanium, silicon, lead, selenium, zirconium, cobalt, chromium, potassium, phosphorus, sulfur, chlorine, calcium, magnesium, sodium, i.e. pea beans are characterized by their rich mineral composition. In mature pea grains carbohydrates are less, while starch is more. All substances in pea beans have a beneficial impact on the health of the body. Pea is useful in anemia and obesity; it also improves the function of the liver, kidneys, cardiovascular system. Green peas exhibit antiseptic properties. The cellulose in the pea beans helps cleaning the stomach and intestines from slag; nicotinic acid (vitamin PP) maintains cholesterol levels and reduces the risk of cancer; thiamine (vitamin B_1) improves brain function; vitamin H (biotin) demonstrates antioxidant properties, regulates blood sugar, stimulates the activity of the digestive and nervous system.

The aim of the present work was to monitor the changes in the number of viable cells of probiotic lactic acid bacteria and in the titratable acidity of non-traditional pea probiotic yoghurts and beverages during storage at 4±2°C for 20 days.

II. Materials and Methods

The following strains of lactic acid bacteria and yeasts were used in the present research: genus *Lactobacillus*: *Lactobacillus acidophilus* Ar, *Lactobacillus acidophilus* $A29_3$, *Lactobacillus casei* ssp. *casei* Shirota D, *Lactobacillus plantarum* 226-15, *Lactobacillus plantarum* BB 22, Starter MZ_2; yeasts: *Saccharomyces cerevisiae* ssp. *diastaticus* 25-G, provided from the collection of the Department of "Microbiology" at the UFT , Plovdiv.

2. Media:

2.1. Sterile skimmed cow milk with titratable acidity 16-18ºT.

2.2. Saline solution. Composition(g/dm^3):NaCl-5.

2.3. Medium for mold and yeast detection in milk and milk products at 25°C according to ISO 6611/2004.

2.4. Medium for staphylococci (*Staphylococcus aureus*) - Baird Parker agar base - 9,47 g of the medium were dissolved in 150 cm^3 of distilled water, then the medium was autoclaved and cooled and then 7,9 cm^3 egg - yolk emulsion were added.

2.5. Medium for the determination of *Salmonella* sp. by horizontal process for isolation of *Salmonella* sp. according to BS EN ISO 6579/2003.

2.6. Medium for coliforms (*E. coli*). Chromocult TBX agar.

2.7. Medium for the determination of the total number of aerobic and facultative anaerobic microorganisms - PCA-agar according to BS ISO 6610:2002. Composition (g/dm^3) - casein peptone – 5,0, yeast extract - 2.5, dextrose – 1,0, agar - 15; pH 7,0 ± 0,2 at 25°C.

2.8. Pea milk

To obtain pea milk smooth pea beans imported from China were used. Dry pea beans were soaked in water for 24 hours. Pea beans and water were mixed in a Russian launcher "Soevaya corova" and were processed with direct steam from the steam generator. During the steam supply grinding the seeds and water vapor extraction at 110°C for 1 hour were performed. The resulting extract was filtered and used as "pea milk".

III. Results and Discussion

The ability of the probiotic strains of lactic acid bacteria and yeasts and yoghurt starters with the probiotic strain *Lactobacillus delbrueckii* ssp. *bulgaricus* MZ_2 to develop in a medium containing pea milk was examined in a series of experiments. It has been found that the use of pea milk alone for the preparation of food products and beverages is not possible due to the high content of starch in it. Therefore, as a medium for the development of the lactobacilli, yeasts and yoghurt starters were prepared media with different dilutional ratio of the pea milk in other media (10% skimmed cow milk or 0,5% NaCl solution), in order to determine the most suitable quality and quantity composition of the culture medium for the preparation of non-traditional dairy products.

The results of previous studies of our team suggest that the best yogurt and beverages are obtained using media containing skimmed cow milk and pea milk in a ratio of 1:1 and skimmed cow milk and pea milk in a ratio of 1:4, while the best quality boza is obtained using a medium consisting of skimmed cow milk and pea milk in a ratio of 1:1 or pea milk and 0,5% NaCl solution in a ratio of 1:1.

A second series of yoghurts, beverages and boza were prepared using the selected media composition and the selected probiotic strains of lactobacilli, yeasts and yoghurt starters.

Pea yoghurts were prepared with the yoghurt starter MZ_2 (Figure 1, Figure 2) in a medium

containing skimmed cow milk and pea milk in different ratios. In the cultivation of each of the strains *Lactobacillus acidophilus* $A29_3$ (Figure 3), *Lactobacillus plantarum* 226-15 (Figure 4, Figure 5) or *Lactobacillus acidophilus* Ar (Figure 6) in a medium containing skimmed cow milk and pea milk pea beverages for immediate consumption were obtained.

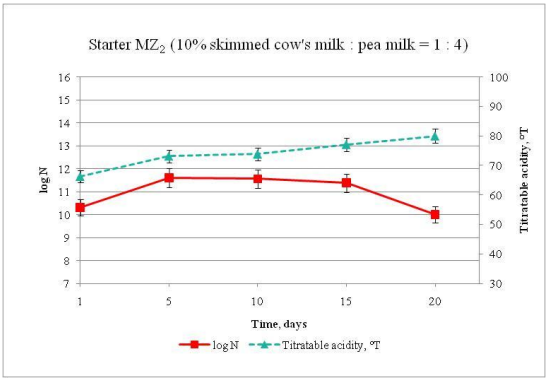

Figure 1. *Change in the concentration of viable cells and in the titratable acidity during 20 days of storage of the pea yogurt obtained with starter MZ_2 in a medium containing skimmed cow milk:pea milk=1:4*

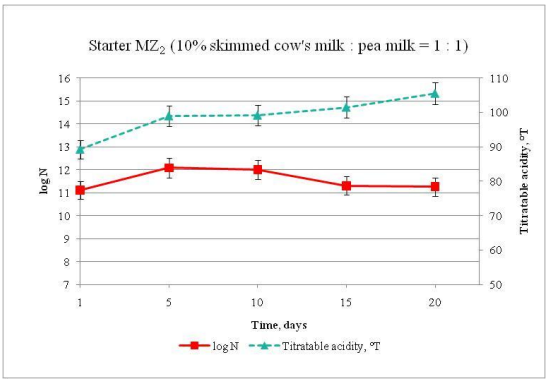

Figure 2. *Change in the concentration of viable cells and in the titratable acidity during 20 days of storage of the pea yogurt obtained with starter MZ_2 in a medium containing skimmed cow milk:pea milk=1:1*

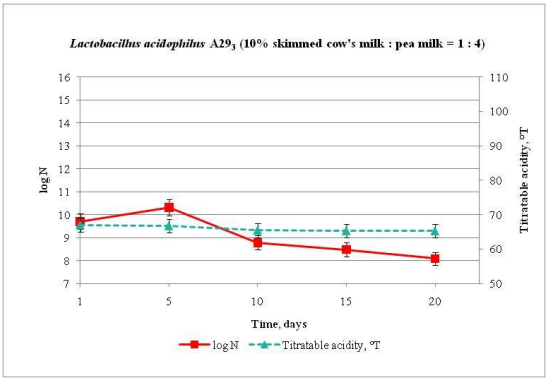

Figure 3. *Change in the concentration of viable cells and in the titratable acidity during 20 days of storage of the pea acidophilic yoghurt obtained with Lactobacillus acidophilus $A29_3$ in a medium containing skimmed cow milk:pea milk=1:4*

Lactobacillus plantarum BB 22 had been isolated from fermented cereals. It was used for the preparation of boza. The latter was obtained by separate cultivation of lactobacilli and yeasts, after which their cultural suspensions were mixed in a ratio of 1:2, respectively. The resulting beverage is weakly acidic without any pea off-flavor (Figure 7).

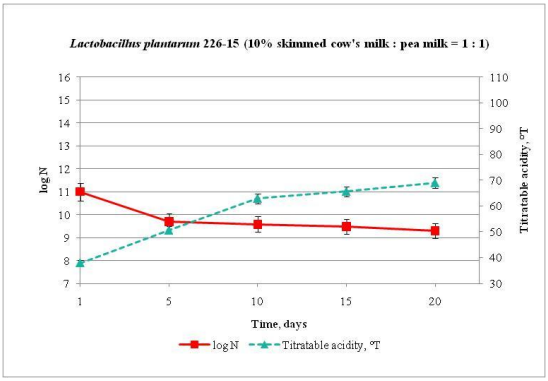

Figure 4. *Change in the concentration of viable cells and in the titratable acidity during twenty days of storage of the pea concentrate obtained with L.plantarum 226-15 in a medium containing skimmed cow milk:pea milk=1:1*

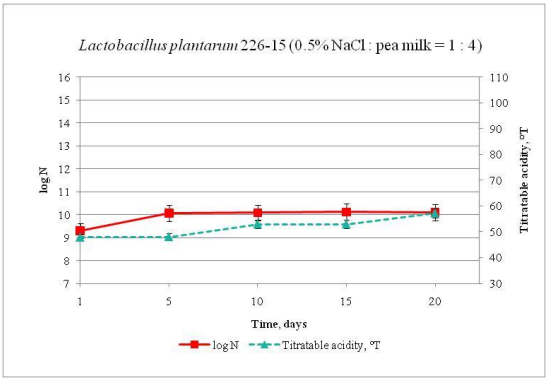

Figure 5. *Change in the concentration of viable cells and in the titratable acidity during twenty days of storage of the pea concentrate obtained with L.plantarum 226-15 in a medium containing 0.5% NaCl solution:pea milk=1:4*

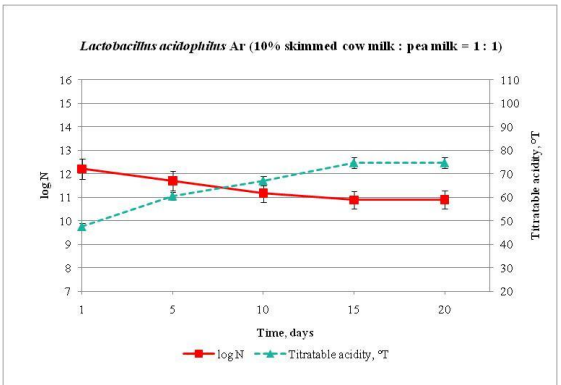

Figure 6. *Change in the concentration of viable cells and in the titratable acidity during twenty days of storage of the pea acidophilic milk obtained with L.acidophilus Ar in a medium containing skimmed cow milk:pea milk=1:1*

Two variants of boza were obtained: Option 1, which contained the cultural suspensions of *Lactobacillus plantarum* 226-15 and *Saccharomyces cerevisiae* ssp. *diastaticus* 25-G mixed in a ratio of 0,5:1; and Option 2, which contained the cultural suspensions of *Lactobacillus plantarum* BB 22 and *Saccharomyces cerevisiae* ssp. *diastaticus* 25-G mixed in a ratio of 0,5:1.

Beverages were prepared with representatives of *Lactobacillus acidophilus*, *Lactobacillus plantarum*, *Lactobacillus casei* ssp. *casei* Shirota D (Figure 8). In addition to the inherent properties of the pea milk these beverages were characterized by a high concentration of viable cells of probiotic bacteria ($5,0x10^9$-$1,6x10^{12}$cfu/cm^3) and moderate titratable acidity, thus increasing their biological value.

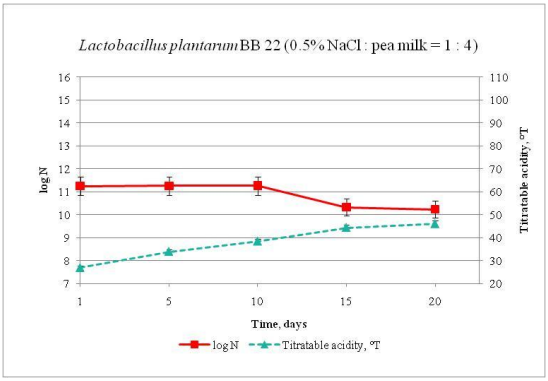

Figure 7. *Change in the concentration of viable cells and in the titratable acidity during 20 days of storage of the pea concentrate obtained with L.plantarm BB 22 in a medium containing 0.5% NaCl solution:pea milk=1:4*

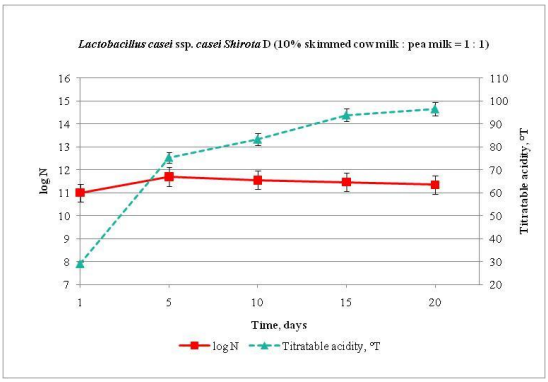

Figure 8. *Change in the concentration of viable cells and in the titratable acidity during 20 days of storage of the pea concentrate obtained with L.casei ssp. casei Shirota D in a medium containing skimmed cow milk:pea milk=1:1*

On the 1st day of storage the content of active cells exceeds 10^9cfu/cm^3 in all foods and beverages. In the two pea yoghurts the ratio of rods to cocci ranges from 1:2 (in a medium containing skimmed cow milk and pea milk in a ratio of 1:4) to 1:1 (in a medium containing skimmed cow milk and pea milk in a ratio of 1:1). This showed that these products contained a considerable amount of the probiotic strain *Lactobacillus delbrueckii* ssp.*bulgaricus* MZ_2.

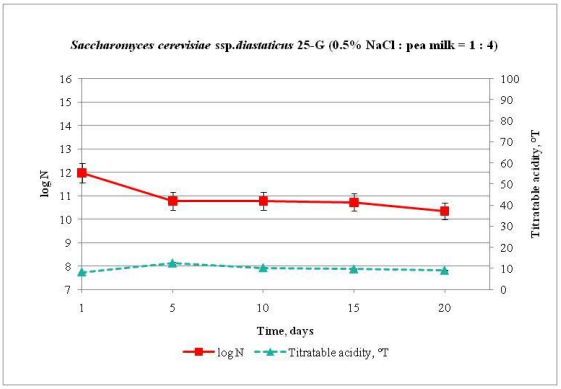

Figure 9. *Change in the concentration of viable cells and in the titratable acidity during 20 days of storage of the pea concentrate obtained by Saccharomyces cerevisiae ssp. diastaticus 25 -G in a medium containing 0.5% NaCl solution and pea milk in a ratio of 1:4*

The resulting dairy foods were stored at 4±2°C for 20 days and the change in the concentration of viable cells of probiotic bacteria and in the titratable acidity were monitored taking samples every five days. The results are shown on Figure 1 to Figure 9.

During storage of the yogurts and beverages at 4±2°C for 5 days slight changes in the number of viable cells of the probiotic cultures or in the titratable acidity were observed.

Upon further storage the same trend was observed. In ten days' storage of the fermented beverages and yogurt, there was no significant change in the amount of viable cells and in the titratable acidity of the medium as well as in the side microflora (Figure 1 - Figure 9).

Table 1. *The side microflora of the fermented pea milk foods and beverages during storage (0 - 20 days) at 4±2°C.*

Indicator	Total number of anaerobic and facultative anaerobic bacteria, cfu/cm^3	Specific microorganisms, cfu/cm^3			Molds and yeasts, cfu/cm^3
		E.coli (TBX-agar)	*Staph. aureus*	*Salmonella* sp.	
Control 1	<1	<10	Not found	Not found	<10
Control 2	<1	<10	Not found	Not found	<10

During fifteen days of storage at refrigerated temperature all fermented pea milk foods retain high concentration of viable cells (over 10^9cfu/cm^3) and moderate titratable acidity.

By the 20th day of storage of the fermented pea milk foods at refrigeration temperature the viability of the cultures was preserved, the number of rods exceeded 10^9cfu/cm^3, which is a basic requirement for the content of beneficial microflora in a food to

be considered a functional food [10]. The values for the titratable acidity of the fermented foods remained moderate. There were no significant changes in the side microflora of the pea foods and beverages (Figure 1 - Figure 9, Table 1).

IV. Conclusion

Using the selected starters and lactobacilli and yeast strains able to grow in a medium containing pea milk were obtained functional pea yogurt with a high concentration of viable cells (over 10^9cfu/cm^3) and moderate titratable acidity and pea acidophilic beverages containing more than 10^9cfu/cm^3 living cells and having moderate titratable acidity. Both types of food can be stored at refrigeration temperatures and administered as highly active probiotic concentrates up to the 20th day of storage.

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FREEZE-DRIED SOURDOUGH STARTERS

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Abstract. *Selected probiotic strains of lactobacilli and propionic acid bacteria were used for the development of sourdough starters for wheat and rye bread. The developed starters were immobilized and freeze-dried using combined hydrocolloid matrix - high-ester pectin and sodium alginate. Biotechnology with the following main stages: selection, immobilization of the selected strains in the hydrocolloid matrix, cryoprotection, freezing and freeze-drying was applied. The survival of the microorganisms in the composition of the two lyophilized starters after freeze-drying and during storage for 12 months was monitored - the probiotic lactobacilli and propionic acid bacteria retained high concentrations of active cells – around 10^{12}CFU/g. The hydrocolloids used were suitable agents for the mechanical immobilization of cell cultures and as cryoprotectants during the lyophilization of the sourdough starters. The sourdough starters were successfully recovered and used for the preparation of rye and wheat bread in different percentage – 10%, 15% and 20%. It was established that the inclusion of 10% of the starter sourdoughs prevented bacterial spoilage and the inclusion of 15% to 20% of starter sourdoughs prevented mold spoilage. The combined biotechnology made possible the preparation of freeze-dried sourdough starters with long shelf life to be applied in the production of wheat and rye bread and bakery products without preservatives with prolonged shelf life.*

Keywords: Probiotic, sourdough, bread, starter, *Lactobacillus*, *Propionibacterium*, immobilization, cryoprotection, freezing, freeze-drying (lyophilization), bacterial spoilage, mold spoilage

I. Introduction

There are two major problems when incorporating a probiotic strain into a food matrix: the resistance of the probiotic to the technological conditions of the food production [29] and the maintenance of its viability up to the expiring date of the food. That could lead to limitation of the use of probiotics in long-life products especially if they are not refrigerated during storage. Freeze-drying is one of the most common methods used to preserve probiotics. But as a method it is not considered optimal, because it just protects probiotics from the humidity [18]. Quite a frequent issue is that probiotics experience decreased viability during or after lyophilization.

Microencapsulation is a process in which the cells are retained within an encapsulating matrix or membrane. Microencapsulation may provide an approach for protecting probiotics as it would allow the isolation of a probiotic from the environment thus increasing its resistance to the conditions of production and would also improve its viability throughout the storage. The protective effect of microencapsulation is due to the limited diffusion of inhibitory substances such as metabolic products from starter cultures, H_2O_2, lactic acid, and bacteriocin into the capsules [16, 23].

Various materials have been used for microencapsulation of probiotics, such as alginate [22], κ-carrageenan [1], cellulose acetate phthalate [11], gelatin [2] and pectin [13, 16].

Freeze-drying of lactic acid bacteria (LAB) ensures their preservation for a long period of storage and low cost transportation. The resulting products are ready-to-use cultures for dairy and other food-related industries, including in the emerging and continuously growing field of probiotics. In order to apply low rates of freezing, which are considered advantageous in industrial production of lactic acid starters as they are of lower cost than high freezing rates (e.g. liquid nitrogen), suitable cryoprotective agents should be employed [5]. A number of cryoprotective agents have been proposed to provide a low cell damage percentage during freeze-drying and subsequent storage, such as various sugars (e.g. glucose, fructose, lactose, mannose), sugar alcohols (e.g. sorbitol and inositol) and non-reducing sugars (e.g. sucrose, trehalose) [30].

The hydrocolloids used in the present research are sodium alginate and high-ester pectin and they act as

matrices for the immobilization of the cell material and as cryoprotectants. They are natural, vegetable raw materials, with well known content of biologically active substances and beneficial physiological effects on the body [12, 17, 26].

Entrapment of probiotic bacteria in alginate matrices has been shown to enhance bacterial cell tolerance to alcohols, phenols, antibiotics or quaternary ammonium sanitizers [19] and resistance to adverse processing techniques such as freezing and freeze-drying and hostile environments such as simulated gastric environment [4].

Bakery products have a very short shelf life. Their quality depends on the time interval between baking and consumption [3]. Spoilage of bakery products is mainly due to the growth of molds, the main species belonging to the genera *Aspergillus, Fusarium* and *Penicillium*, as well as to the roping of the bread, caused by *Bacillus* sp., especially *B. subtilis* and *B. licheniformis* [24]. The freshness of bread depends on the flavor, appearance and crispness of the crust, the hardness of the crumb and the volume of the bread. The taste of the bread, however, is considered the most important feature for consumers, as a criterion for eligibility of the products [28]. During storage, reduction in the freshness of the bread along with the increase of the hardness of the crumb result in loss of acceptable appearance to consumers, a process known as staling [15].

The addition of sourdough is the best technique to keep the bread from spoilage meeting consumer's demand for natural food without additives [7]. Sourdough is a mixture of flour (from wheat, rye, rice, etc.) and water, which is fermented by the action of lactic acid bacteria and yeasts [9]. These microorganisms usually come from flour, dough ingredients or the environment.

There are a number of benefits of the application of sourdough in bread making: improvements in the volume of the bread and the structure of the crumb [6, 8], the flavor, the nutritional value [20, 21] and shelf life [3], due to the delay of the process of staling and the prevention of mold and bacterial spoilage [10, 14]. These positive effects are associated with the metabolic activity of the selected pure cultures of yeast and homo- and heterofermentative lactic acid bacteria in the composition of the sourdough, for example lactic acid fermentation, proteolysis, exopolysaccharide production and synthesis of volatile and antimicrobial compounds [3, 7, 25]. With the inclusion of starter cultures, the pH falls very quickly, so the whole manufacturing process is accelerated, which leads to economic benefits for the producer. The secondary effects of the acidification and the acceleration of the fermentation time include changes in the activity of the enzymes of the cereal substrates or the bacterial strains [3]. In order for those beneficial effects to take place a proper selection of lactic acid bacteria species and strains, an appropriate technology and effective control of the purity and activity of the cultures are required. The selection of pure cultures consists of using a species or a combination of species specific to the technological process, fully adapted to the environment of sourdough and to the applied fermentation conditions [27].

The main objective of the present study is to obtain freeze-dried sourdough starters for wheat and rye bread with long shelf life and to examine the possibilities for the preparation of quality bread using the obtained starters.

II. Materials and Methods

Microorganisms:

Probiotic microorganisms: *Lactobacillus paracasei* RN5, *Lactobacillus plantarum* X2, *Lactobacillus brevis* LBRZ7, *Lactobacillus fermentum* LBRH10, *Lactobacillus buchneri* LBRZ6, *Lactobacillus sanfranciscensis* LSR and *Propionibacterium frendenreichii* ssp. *shermanii* NBIMCC 327.

Media:

MRS-broth. (Scharlau)

MRS-agar. Composition (g/dm^3): MRS-broth (Scharlau) + 2% agar.

Sterile skimmed milk with titratable acidity 16-18ºT. (Scharlau).

Saline solution.

Solid medium for *Bifidobacterium* sp. Composition (g/dm^3): peptone - 10, yeast extract - 10 lactose - 10, $MnSO_4$ - 1 casein hydrolyzate - 8, NaCl - 3.2, CH_3COONa – 1, agar - 20. pH is adjusted to 6.6 - 6.8. Sterilization - 20 minutes at 121°C.

Elective medium for *Propionibacterium* sp. Composition (g/dm^3): tryptone - 10, yeast extract - 10; Na-lactate (fresh) – 10 cm^3, KH_2PO_4 – 2.5, $MnSO_4$ – 0.005, agar – 15; pH is adjusted to 6.8. Sterilization - 20 minutes at 121ºC. *Na-lactate (fresh) - 7 g of Na-lactate lactic acid is neutralized with 3.1 g NaOH crystals and after that the remaining salts dissolved in distilled water are added.

Hydrocolloid matrices: pectin + sodium alginate / 1:1 / - 1.2% solution of sodium alginate, and 4% solution of pectin.

The concentrations of the hydrocolloid solutions were determined on the basis of the physicochemical parameters of the hydrocolloids used.

Obtaining of freeze-dried concentrates - a three-stage technology with the following stages:

1. Primary processing the cellular suspensions of the sourdough starter combinations of lactic acid bacteria and propionic acid bacteria were diluted, equilibrated, dosed and immobilized by inclusion in the polymer matrix that acts as a cryoprotectant. These processes were performed before freezing.

2. Freezing in chambers with forced convection of the air environment at a temperature of -30°C to -35°C for 12-15 hours.

3. Freeze-drying performed in a vacuum sublimation installation "Hochvakuum-TG - 16.50" with contact heating of the plates in the ICFT - Institute of Cryobiology and Food Technologies, Sofia, Bulgaria.

After lyophilization, the lyophilizates were digested in the granulator "Erveka". The digested lyophilized soutdough starters were packed in three layer aluminum foil, sealed under vacuum.

Microbiology

1. The microbiological status of the freeze-dried sourdough starters - acc. BS 1670-82 and Ordinance № 5 of the MH - SG 39/84, BS EN ISO 4833.

Indicators:

• lactic acid bacteria and propionic acid bacteria - CFU/g;

• total number of mesophilic aerobic and facultative anaerobic microorganisms - CFU/g;

• coliforms in 0.1 g of product;

• pathogens including *Salmonella* sp. in 25.0 g of product;

• pathogenic staphylococci in 1.0 g of product;

• sulfite reducing clostridia in 0.1 g of product;

• spores of microscopic molds, CFU/g;

• yeasts, CFU/g;

Approbation of the starter cultures for wheat bread in the production laboratory

Recovered sourdough starters were obtained by 60-hour cultivation of the 8-month old freeze-dried sourdough starters in MRS-broth at 30°C. After that the recovered freeze-dried sourdough starters and the non-recovered freeze-dried sourdough starters were used for the preparation of sourdoughs for wheat or rye bread. The sourdoughs were refreshed daily for the duration of two weeks. "Mother" doughs with 10% of the two-week old recovered starter sourdoughs or of the two-week old non-recovered freeze-dried starter sourdoughs were prepared. Each dough was prepared with 1.5% NaCl, 2% yeast starter, the respective percentage of the respective starter sourdough and tap water (the amount of water was determined by the water absorption of the type of flour). The dough was kneaded in a mixer: slow kneading (1000 rpm) for 4 min and fast kneading (1400rpm) for 10 min. After that the dough was rested for about 10 min in a proofer in order for its elastic properties to be improved. Loaves were formed and placed in the forms. Then followed leavening for about 40-45 min at 30°C and 80±5 RH. In the production laboratory wheat bread with sourdough as well as control bread (bread without sourdough with starter) were baked, cooled and evaluated. Baking was carried out at 225±5°C for 30 min in a deck oven. Loaves were allowed to cool for 120 min at room temperature.

Determination of bacterial and mold spoilage of baked bread

The determination of the appearance of bacterial and mold spoilage was performed by 10 trained judges in the production laboratory and was evaluated according to a scale of I to IV, with each of the degrees corresponding to the following descriptions:

I – barely noticeable (pleasant fruity odour)

II – weak (change in the odour - distinct)

III – medium (moisty, sticky crumb, sharp odour)

IV – strong (unpleasant odour, brown-yellow crumb)

III. Results

The strains *Lactobacillus paracasei* RN5, *Lactobacillus plantarum* X2, *Lactobacillus brevis* LBRZ7, *Lactobacillus fermentum* LBRH10, *Lactobacillus buchneri* LBRZ6, *Lactobacillus sanfranciscensis* LSR and *Propionibacterium frendenreichii* ssp. *shermanii* NBIMCC 327 with proven probiotic properties were used for the development of two sourdough starters: wheat starter, consisting of Basic Combination : *Lactobacillus sanfranciscensis* LSR : *Propionibacterium frendenreichii* ssp. *shermanii* NBIMCC 327 in a ratio of 2 : 1 : 1; and rye starter, consisting of Basic Combination : *Lactobacillus buchneri* LBRZ6 : *Propionibacterium frendenreichii* ssp. *shermanii* NBIMCC 327 in a ratio of 2 : 1 : 1. The Basic Combination included *Lactobacillus paracasei* RN5 : *Lactobacillus plantarum* X2 : *Lactobacillus brevis* LBRZ7 : *Lactobacillus fermentum* LBRH10 in a ratio of 1 : 2 : 1 : 1. The two starters were cultured in a laboratory bioreactor with a working volume of 1.5 dm^3 at constant stirring at a rate of 150 rpm at 37±1°C.

The bioreactor was equipped with a control unit "Sartorius A2" that included control devices for the stirring rate, the temperature, the pH and other parameters. Immobilization in the presence of a hydrocolloid matrix consisting of high-ester apple pectin and sodium alginate was performed. It was followed by freeze-drying of the three strains. The resulting lyophilized sourdough starters were stored at 20°C - 22°C and the dynamics of cellular survival of lactobacilli and propionic acid bacteria for 12 months of storage was monitored (Figure 1 and Figure 2).

The examinations of the lyophilized sourdough starters according to the standard methods show absence of insemination with pathogenic microflora (Table 1):

Table 1. *Microbiological status of the probiotic lyophilisates*

Type of pathogens	Norm according to BS	Number of tested microorganisms, CFU/g
1. General number of mesophilic aerobic microorganisms, CFU/g	No more than 800	360
2. Coliform bacteria in 0.1 g of the product	Not to be found	Not found
3. Sulfite reducing clostridia in 0.1 g of the product	Not to be found	Not found
4. *Salmonella* sp. in 25.0 g of the product	Not to be found	Not found
5. *Staphylococcus aureus* in 1.0 g of the product	Not to be found	Not found
6. Spores of microscopic molds, 100 CFU/g	No more than 100	25 -35
7. Yeasts, CFU/g	No more than 100	38 – 50

No pathogenic microorganisms were found in the freeze-dried sourdough starters. Both of them meet the standard requirements for microbial purity of food.

In the process of freeze-drying the number of viable cells decreased slightly - by less than 1logN both for lactobacilli and propionic acid bacteria. This effect was due to the optimally conducted process, including using a combined cryoprotectant hydrocolloid matrix.

Sodium alginate and high-ester apple pectin (the hydrocolloids used for the mechanical immobilisation of the probiotic strains of microorganisms, as well as as a cryoprotectant medium) proved to be highly efficient, as evidenced by the high survival rate of the freeze-dried microorganisms.

The survival of the freeze-dried concentrates, i.e. the resistance of the organism during long-term storage, was monitored. The lyophilized sourdough starters were stored at 20°C - 22°C for 12 months, taking samples every three months and determining the number of viable cells. The results of this examination are shown on Fig. 1 for the wheat starter and on Fig. 2 for the rye starter.

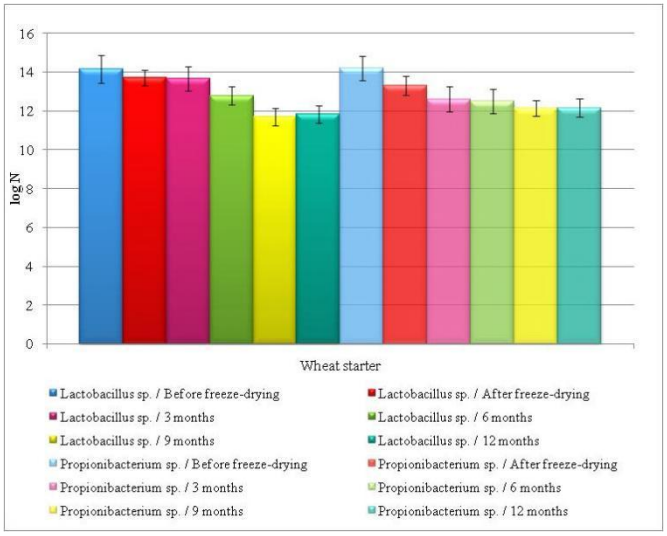

Figure 1. *Survival of the cells of Lactobacillus sp. and Propionibacterium sp. in the composition of the freeze-dried wheat sourdough starter after lyophilization and during storage of the freeze-dried bioproduct for 12 months at 20°C - 22°C.*

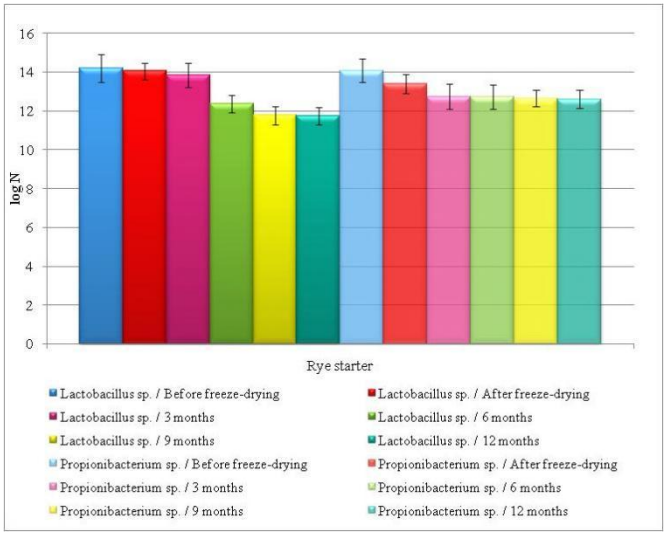

Figure 2. *Survival of the cells of Lactobacillus sp. and Propionibacterium sp. in the composition of the freeze-dried rye sourdough starter after lyophilization and during storage of the freeze-dried bioproduct for 12 months at 20°C - 22°C.*

The recovered and the non-recovered freeze-dried sourdough starters for wheat and rye bread were refreshed daily for two weeks. The change in the total titratable acidity (TTA) and the aroma of the sourdoughs were monitored. Determination of the number of viable cells of lactobacilli, propionic acid bacteria and yeasts on the 96th hour as well as a microscopic visualization were conducted. The results demonstrated full recovery of the two sourdough starters in the process of daily refreshment of the prepared sourdoughs for the duration of two weeks. Moreover, there was no significant difference between the sourdoughs prepared with recovered or non-recovered starters by the end of the second week of daily refreshment.

Highly contaminated flours with *Bacillus* spores (over 10^2cfu/g) were used to determine the bacterial and mold spoilage of the baked variants of bread. The baked breads with 10%; 15% or 20% of the two-week starter sourdoughs were incubated in non-aseptic conditions in parallel experiments at room temperature and in a thermostat at 37°C and at room temperature for 96 hours for bacterial spoilage and for 120 hours at 30°C and at room temperature for mold spoilage.

Table 2. *Bacterial bread spoilage by Bacillus sp. during incubation of the baked breads at 37°C and at room temperature. DS = Degree of Spoilage*

Variants	Temperature	24 h		48 h		72 h		96 h	
		DS	Aroma	DS	Aroma	DS	Aroma	DS	Aroma
Control	37°C	-	No	I	Yes	II	Yes	III	Yes
	Room temperature	-	No	-	No	I	Yes	II	Yes
Rye starter sourdough; 10%	37°C	-	No	-	No	I	Yes	II	Yes
	Room temperature	-	No	-	No	I	Yes	II	Yes
Rye starter sourdough; 15%	37°C	-	No	-	No	-	No	-	No
	Room temperature	-	No	-	No	-	No	-	No
Rye starter sourdough; 20%	37°C	-	No	-	No	-	No	-	No
	Room temperature	-	No	-	No	-	No	-	No
Wheat starter sourdough; 10%	37°C	-	No	-	No	I	Yes	II	Yes
	Room temperature	-	No	-	No	I	Yes	II	Yes
Wheat starter sourdough; 15%	37°C	-	No	-	No	-	No	-	No
	Room temperature	-	No	-	No	-	No	-	No
Wheat starter sourdough; 20%	37°C	-	No	-	No	-	No	-	No
	Room temperature	-	No	-	No	-	No	-	No

I – barely noticeable (pleasant fruity odour); II – weak (change in the odour - distinct); III – medium (moisty, sticky crumb, sharp odour); IV – strong (unpleasant odour, brown-yellow crumb)

Table 3. *Mold bread spoilage during incubation of the baked breads at 37°C and at room temperature*

Variants	Temperature	24 h	48 h	72 h	96 h	120 h
Control	30°C	No	No	Yes	Yes	Yes
	Room temperature	No	No	Yes	Yes	Yes
Rye starter sourdough; 10%	30°C	No	No	No	Yes / No – single colonies	Yes
	Room temperature	No	No	No	Yes / No – single colonies	Yes
Rye starter sourdough; 15%	30°C	No	No	No	No	Yes
	Room temperature	No	No	No	No	No
Rye starter sourdough; 20%	30°C	No	No	No	No	No
	Room temperature	No	No	No	No	No
Wheat starter sourdough; 10%	30°C	No	No	No	Yes / No – single colonies	Yes
	Room temperature	No	No	No	Yes / No – single colonies	Yes
Wheat starter sourdough; 15%	30°C	No	No	No	No	Yes
	Room temperature	No	No	No	No	No
Wheat starter sourdough; 20%	30°C	No	No	No	No	No
	Room temperature	No	No	No	No	No

It was established that bacterial spoilage resulting from the growth of representatives of *Bacillus* sp. occured earlier in the control loaf incubated at 37°C than in that incubated at room temperature. Bacterial spoilage in the control bread became noticeable on the 48th hour after taking the loaves out of the oven at 37°C and on the 72nd hour at room temperature. According to the standard requirements there should be no signs of bacterial decay up to the 48th hour. The control bread did not meet the standard requirements for microbial safety of bakery products. Upon addition of 10% of starter sourdough there were signs of bacterial spoilage on the 72nd hour both at 37°C and at room temperature. If the inclusion of sourdough reached 15%, in the obtained sourdough bread there were no signs of bacterial spoilage even on the 96th hour both at 37°C and at room temperature. Upon addition of 20% of sourdough no bacterial spoilage was established as well (Table 2).

The earliest appearance of mold spoilage was in the control bread – on the 72nd hour both at 30°C and at room temperature. Upon addition of 10% of sourdough the first signs of mold spoilage became noticeable on the 96th hour both at 30°C and at room temperature. If the percentage of incorporation of starter sourdough in the breadmaking process was increased to 15%, mold spoilage became visible on the 120th hour in the variants stored at 30°C. Upon addition of 20% of sourdough there was no mold spoilage even at the 120th hour (Table 3).

IV. Discussion

The absence of insemination with pathogenic microorganisms proves that the overall process is performed out in accordance with the sanitary standards and requirements. The very technology of freeze-drying has a bactericidal effect and does not create conditions for insemination of the freeze-dried product. Moreover, the higher the degree of dehydration is (in our bioproducts the residual moisture content was below 5.0%), the lower the survival of the pathogenic microflora is.

The combined hydrocolloid matrix, consisting of sodium alginate and high-ester apple pectin, proved to be effective as cryoprotectant medium.

Probably, as a hydrocolloid matrix for the immobilization of the sourdough starters alginate and pectin ensure the following effects: the significant stabilization of the enzymatic activity of the immobilized cells as well as the stabilization and the increase of the overall activity of the immobilized probiotic system, which is beneficial for the survival of the probiotic microorganisms in the composition of sourdough starters after lyophilization and during storage.

The obtained positive results are associated with the high survival rate of the tested lactobacilli and propionic acid bacteria in the lyophilized biological products and are due to the optimal development of the whole process - freezing conditions, applying appropriate cryoprotectant medium and regime parameters of freeze-drying, proper determination of the duration of the cycle, which provides low residual moisture content in the final lyophilizates, resistance to the thermal processes and extension of their storage.

The best percentage of inclusion of the two starter sourdoughs in the breadmaking process was established to be 10% for prevention of bacterial spoilage and between 15% and 20% for prevention of mold spoilage.

IV. Conclusions

The used combined hydrocolloid matrix of sodium alginate and high-ester apple pectin proved to be a highly effective cryoprotectant of endocellular type that increases the survival of lactobacilli and propionic acid bacteria during lyophilization. During the examined 12-month period no adverse changes in the microbiological purity and activity of the lyophilizates were established. Together with the absence of pathogenic microflora and the low residual moisture content of the new freeze-dried organic bioproducts these are the factors determining the prolonged storage of the freeze-dried sourdough starters. The two sourdough starters recovered fully during daily refreshment of the starter sourdoughs. For the prevention of bacterial spoilage the selected starter sourdoughs had to be in concentration of 10%, while for prevention of mold spoilage this percentage increased to between 15% and 20%.

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ANTIMICROBIAL ACTIVITY OF *LACTOBACILLUS PLANTARUM* BG 24 AGAINST PATHOGENS

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Abstract. *The antimicrobial activity of Lactobacillus plantarum BG 24 isolated from naturally fermented cereal beverage (boza) against pathogens causing intestinal infections - Escherichia coli ATCC 25922, Salmonella sp. (clinical isolate) and Klebsiella pneumoniae was determined by co-culturing of the Lactobacillus strain with each of the pathogens at 37±1°C. It was found that Lactobacillus plantarum BG 24 inhibited the growth of the pathogens and no viable cells of the pathogens were found on the 48th hour. The observed changes in the mixed population were a result of the accumulation of the produced lactic acid and other organic acids which acidify the medium and modify the conditions for the growth of the pathogenic microorganisms.*

Keywords: antimicrobial, pathogen, *Lactobacillus*, co-cultivation

I. Introduction

Lactobacilli and bifidobacteria are natural components of the gastrointestinal microflora of a healthy individual. They are included in the composition of probiotics and probiotic foods, because of their proven health effects on the body [1, 3, 4, 7]. They are the main regulators of the balance of the gastrointestinal microflora [8].

Not all strains of lactobacilli and bifidobacteria can be used as components of probiotics or probiotic foods, but only those that meet certain requirements: to be of human origin; to be non-pathogenic; to be resistant to gastric juice and bile salts; to allow implementation of technological processes that lead to the accumulation high concentrations of viable cells; to have the potential to adhere to the gastrointestinal epithelium; to produce antimicrobial substances; to be resistant to the antibiotics applied in medical practice; to allow industrial cultivation, encapsulation and freeze-drying; to retain their activity in the course of storage and to be safe for food and clinical application [5, 6]. This requires the mandatory selection of bifidobacteria and lactobacilli strains with probiotic properties.

One of the requirements for probiotic strains is to possess antimicrobial activity against conditionally pathogenic, carcinogenic and pathogenic microorganisms, which is associated with inactivation of their enzymatic systems, overcoming their adhesion, inhibiting their growth and ejection of the biological niche, all of these resulting in normalized gastrointestinal microflora.

The purpose of the present study was to determine the antimicrobial activity of the strain *Lactobacillus plantarum* BG 24 isolated from naturally fermented cereal beverage (boza) against 3 pathogens causing food toxicoinfections - *Escherichia coli* ATCC 25922, *Salmonella* sp. (clinical isolate) and *Klebsiella pneumoniae* by co-culturing of *Lactobacillus plantarum* BG 24 with each of the pathogenic microorganisms.

II. Materials and Methods

Media:

1. MRS- broth medium. Composition (g/dm^3): peptone from casein - 10, yeast extract - 4; meat extract - 8, glucose - 20; K_2HPO_4 - 2; sodium acetate - 5; diammonium citrate - 2; $MgSO_4$ - 0.2; $MnSO_4$ - 0.04; Tween 80 - 1 ml; pH = 6.5. Sterilization - 15 minutes at 121ºC.

2. LAPTg10 - broth. Composition (g/dm^3): peptone - 15, yeast extract - 10; tryptone - 10, glucose - 10. pH is adjusted to 6.6 - 6.8 and Tween 80 - 1cm^3/dm^3. Sterilization - 20 minutes at 121ºC.

3. LAPTg10-agar. Composition (g/dm^3): LAPTg10 – broth medium; agar - 20. Sterilization - 20 minutes at 121ºC.

4. LBG-agar. Composition (g/dm^3): tryptone – 10; yeast extract - 5, NaCl - 10, glucose – 10, agar - 20. pH = 7.5. Sterilization - 20 minutes at 121°C.

Determination of antimicrobial activity against pathogenic microorganisms [1]

To determine the antimicrobial activity of the studied *Lactobacillus* strain against pathogens a 48 hour cultural suspension of *Lactobacillus plantarum* BG 24 was used. Separate cultivation of the *Lactobacillus* strain and each pathogen strain as well as joint cultivation of *Lactobacillus plantarum* BG 24 and each of the pathogens included in the study was conducted. The following pathogens were used: *Escherichia coli* ATCC 25922, *Salmonella* sp. (clinical isolate) and *Klebsiella pneumoniae*. For the examination of the joint cultivation 0.5 cm^3 of the

Lactobacillus plantarum BG 24 suspension, 0.5 cm^3 of the suspension of the pathogen and 9 cm^3 of culture medium (MRS-broth) were mixed. In the control of *Lactobacillus plantarum* BG 24 and in the control of each pathogen 9.5 cm^3 of the MRS-broth medium were mixed with 0.5 cm^3 of the suspension of the *Lactobacillus* strain or of the suspension of the pathogen, respectively. The joint cultivation of *Lactobacillus plantarum* BG 24 and each of the pathogenic microorganisms under static conditions in a thermostat at 37±1ºC for 60 hours, taking samples at the 0^{th}, 12^{th}, 24^{th}, 36^{th}, 48^{th} and 60^{th} hour and monitoring the changes in the titratable acidity and the concentration of viable cells of both the pathogens and the *Lactobacillus* strain was performed. Determination of the number of viable cells was done by the spread plate method on LAPTg10-agar (for the enumeration of lactobacilli) or on LBG-agar (for the enumeration of pathogens). The titratable acidity was determined according to a standard protocol [2].

III. Results and Discussion

During the separate cultivation of *Lactobacillus plantarum* BG 24 under static conditions over 9.10^{13}cfu/cm^3 viable cells were accumulated by the 24^{th} hour (Fig. 1, Fig. 3, Fig. 5). For the same time interval the titratable acidity of the medium reached over 200°T (Fig.2, Fig. 4, Fig. 6).

During the separate cultivation of each of the pathogens *Escherichia coli* ATCC 25922, *Salmonella* sp. and *Klebsiella pneumoniae* the number of living pathogen cells reached over 10^{12}cfu/cm^3 for 24 hours of incubation and the high concentration of viable cells was retained by the 60^{th} hour. The change in the titratable acidity of the medium was slight for the 60 hours of separate incubation for all of the three pathogens (Fig. 2, Fig. 4, Fig. 6). During the co-cultivation of *Lactobacillus plantarum* BG 24 and each of the pathogens the proliferation of the *Lactobacillus* strain was not influenced by the presence of any of the pathogens in the medium and the concentration of living lactobacilli cells reached values of 10^{14}cfu/cm^3. At the same time the number of viable pathogen cells decreased and the observed reduction was strain specific (Fig. 1, Fig. 3, Fig. 5).

In the co-cultivation of *Lactobacillus plantarum* BG 24 and *Escherichia coli* ATCC 25922 at 37±1°C the concentration of living cells of the pathogen was gradually reduced and on the 48^{th} hour no viable pathogen cells were detected (Fig. 1).

In the co-cultivation of Lactobacillus plantarum BG 24 and Salmonella sp. (clinical isolate) at 37±1°C a decrease in the number of viable cells of Salmonella sp. was observed since the very beginning of the co-cultivation and on the 48^{th} hour no viable pathogen cells were determined (Fig. 3).

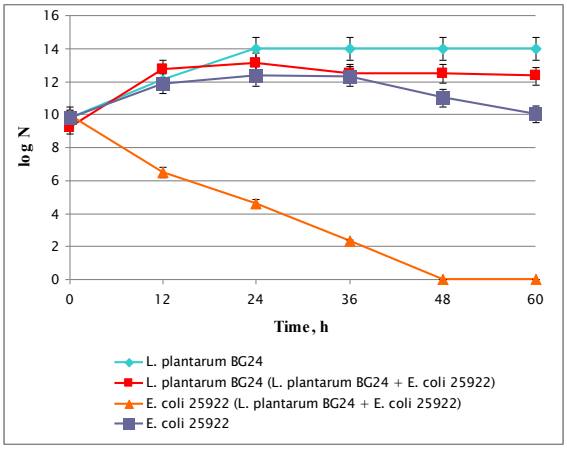

Figure 1. *Survival of Lactobacillus plantarum BG 24 and E. coli ATCC 25922 during separate cultivation and cultivation in a mixed population at 37±1°C*

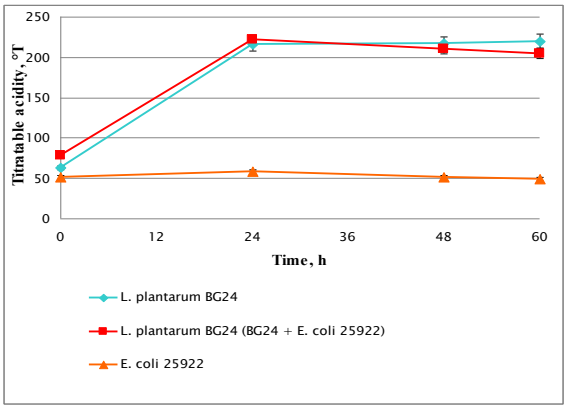

Figure 2. *Changes in the titratable acidity of the medium during separate cultivation and co-cultivation of Lactobacillus plantarum BG 24 and E. coli ATCC at 37±1°C*

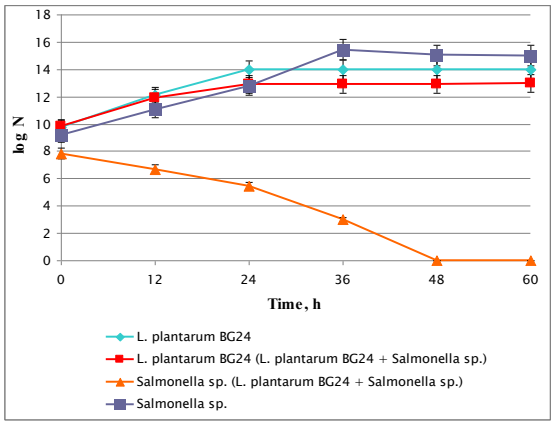

Figure 3. *Survival of Lactobacillus plantarum BG 24 and Salmonella sp. during separate cultivation and cultivation in a mixed population at 37±1°C*

The titratable acidity of the medium on the 48^{th} hour reached 243,6°T (Fig. 4).

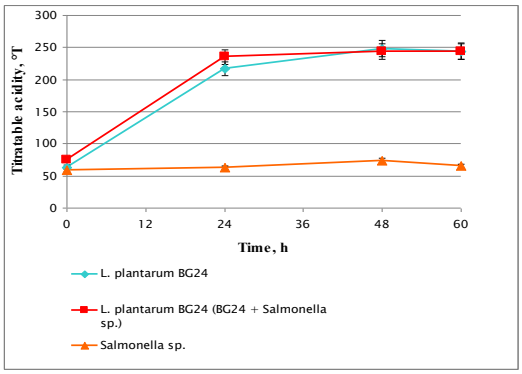

Figure 4. *Changes in the titratable acidity of the medium during separate cultivation and co-cultivation of Lactobacillus plantarum BG 24 and Salmonella sp. at 37±1°C*

Similar relationships were observed in the co-culturing of *Lactobacillus plantarum* BG 24 and *Klebsiella pneumoniae*. The number of viable cells of *Klebsiella pneumoniae* was reduced and by the 48th hour practically no active cells of the pathogen were defined (Fig. 5, Fig. 6).

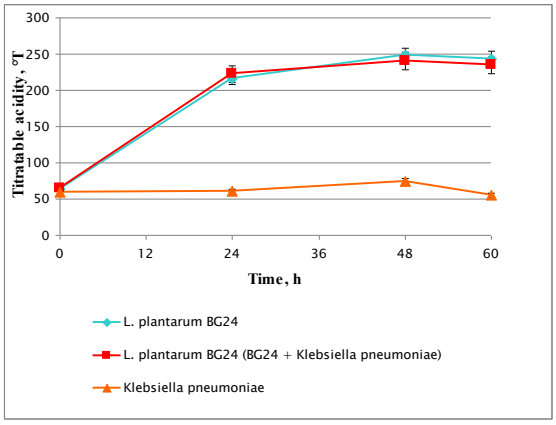

Figure 5. *Survival of Lactobacillus plantarum BG 24 and Klebsiella pneumoniae during separate cultivation and cultivation in a mixed population at 37±1°C*

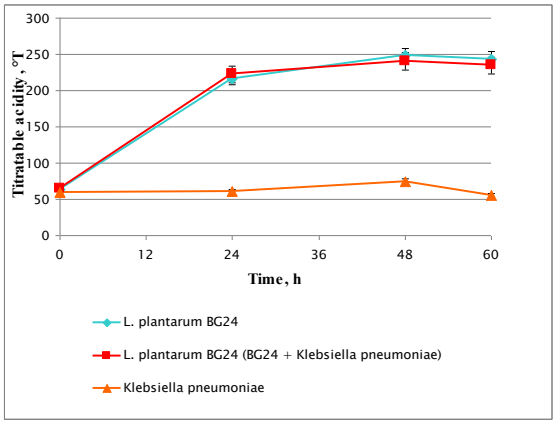

Figure 6. *Changes in the titratable acidity of the medium during separate cultivation and co-cultivation of Lactobacillus plantarum BG 24 and Salmonella sp. at 37±1°C*

The observed reduction in the number of pathogen cells during the co-cultivation of Lactobacillus plantarum BG 24 and each pathogen was due to a great extent to the increased titratable acidity of the medium, resulting from the production and accumulation of lactic acid and other organic acids in the medium (Fig. 2, Fig. 4, Fig. 6).

IV. Conclusion

Lactobacillus plantarum BG 24 retained high concentration of viable cells during co-cultivation with *Escherichia coli* ATCC 25922, *Salmonella* sp. or *Klebsiella pneumoniae* at 37±1°C, while that of the pathoges decreased, the dynamics of reduction of pathogen cells being strain specific. The observed reduction in the concentration of living cells of the pathogens to a great extent was a result of the increased titratable acidity of the medium, due to the production and accumulation of lactic acid and other organic acids in the medium. The demonstrated high antimicrobial activity of *Lactobacillus plantarum* BG 24 makes it suitable for use in functional starters for cereal foods.

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INFLUENCE OF THE PUNT SIZE OVER SOME PHYSICAL QUANTITIES OF A CHAMPAGNE BOTTLE

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Abstract. *The influence of the bottom shape over some basic physical parameters of a champagne bottle – principal stresses when it is subjected to internal pressure, total volume and mass of the bottle - is studied. Software, developed by Dassault Systemes (France), is used for computational modeling and simulation of the bottle subjected to internal pressure. An optimal shape of the champagne bottle's bottom is proposed.*

Keywords. Champagne bottle, punt size, lightweighting, internal pressure, principal stress, computer simulation.

I. Introduction

The champagne bottle, one of the most massive glass bottles ever produced, has been developed significantly as shape and dimensions in the last decades. The aim is the utmost degree of lightweighting of the bottle while maintaining its functionality. An example of the champagne bottle progress is table 1.

Table 1. *Champagne bottles progress over last two decades*

Specimen	Year of production	Volume, ml	Wall thickness, mm	Bottom thickness, mm	Mass, g	Tested at pressure, MPa
1	1985	750	4,5	7	935	1,7
2	2009	750	1,5	3	600	1,4
3	2009	750	2,5	4	640	1,4
4	2009	750	n/a	n/a	635	1,7

Specimen 1 – Bulgarian champagne bottle BDS 7827-84
Specimen 2 – Champagne bottle produced by GCC, Moldova
Specimen 3 – Champagne bottle produced by Angelis SRL, Romania
Specimen 4 – Champagne bottle produced by Орехово-Зуевская Стекольная Компания, Russia

The fundamental experimental study of glass bottles subjected to internal pressure is a research carried out by Teague and Blau in 1956 [1]. Contemporary studies of the problem (Cannon, et al., 2004) [2] used high speed camera for the experimental research and numerical procedures (finite elements analyses) for computer simulations of the glass bottle response when it is subjected to internal pressure. Assessing the validity of the computer results and verification of the computer simulation was conducted by comparison with theoretical analysis and calculation [4]. It was theoretically proven that the maximum value of first principal stress (tensile stress) occurred at the transition zone from the bottom to the cylindrical body of the bottle [3]. These theoretical results were in excellent agreement with the experimental results (figure 1) [1]. That indicates that the bottom shape of the bottle is of great importance for mechanical strength of glass bottles subjected to internal pressure.

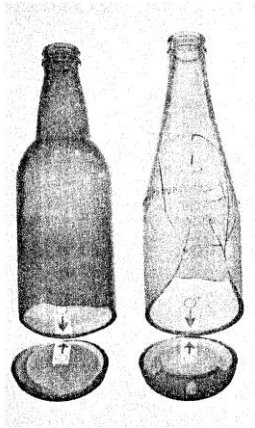


Figure 1. *Prevalent bottle breakage when it is subjected to internal pressure [1]*

The aim of this paper is to study the influence of the bottom punt size over some basic physical parameters of a champagne bottle like principal stresses when it is under internal pressure, total volume and mass. This study is focused on finding

the optimal bottom shape from strength and functional perspective.

II. Computer simulation

To accomplish a computer simulation of a champagne bottle response, when it is subjected to internal pressure, is used CAD software developed by Dassault Systemes (France). Three-dimensional models of champagne bottles with different size of the punt at the bottom are created. The bottom is modeled with different curvatures of generatrix and the main parameter for the degree of concavity is the height *H* at the bottom of the mould forming the external shape (figure 2). The radius of curvature at the transition zone between bottom and cylindrical body is kept constant for all the modeled bottles. The wall thickness is 4,5 mm and the bottom thickness is 6.8 mm. These are the dimensions set in BDS 7827-84 standard and it can be considered as a starting point for optimizing the dimensions and lightweighting the champagne bottle.

Strength analysis is carried out by using finite elements method. For linear static problem with more than 100 000 degrees of freedom (DoF), without varying material stiffness it is appropriate to be used iterative FFEPlus solver. For generating a mesh and computation is used 3D tetrahedral finite element with 10 nodes and 30 DoF. The dimension between nodes is 2 mm.

The boundary conditions (figure 3) when simulating internal pressure loading are: fixed inner surface at the bottle neck and uniformly distributed pressure normal to inner surface of the bottle with magnitude of 0,5 MPa, identical with the maximum magnitude of internal pressure in bottled champagne.

Material properties for glass are – Elastic modulus - 69 GPa, Poisson ratio - 0.23, density - 2458 kg/m^3.

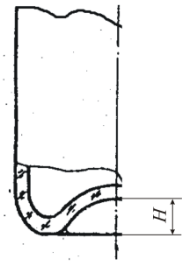


Figure 2. *Punt size of a bottle*

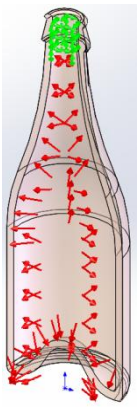
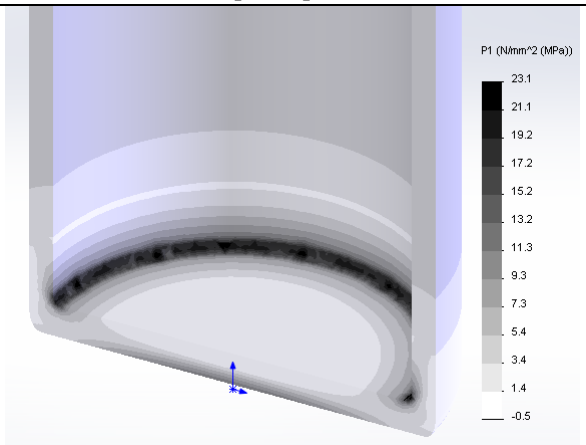
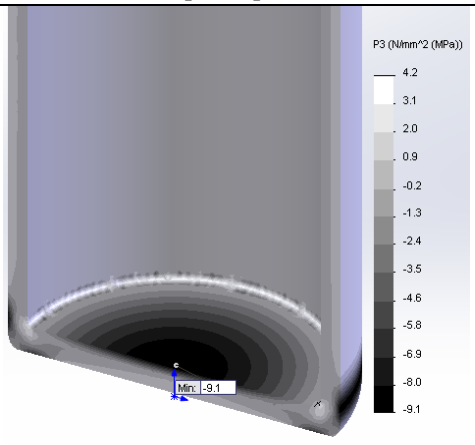


Figure 3. *Boundary conditions*

III. Results and discussion

The results from the computer simulation for different champagne bottles subjected to 0,5 MPa internal pressure and their physical properties are presented in table 3. The distribution of first principal stress and third principal stress for champagne bottles with different punt size at the bottom are shown in table 2.

Table 2. *Stress distribution at the bottom of champagne bottles with different punt size under internal pressure of 0,5 MPa*

	First principal stress	Third principal stress
Height at the bottom 0 mm		

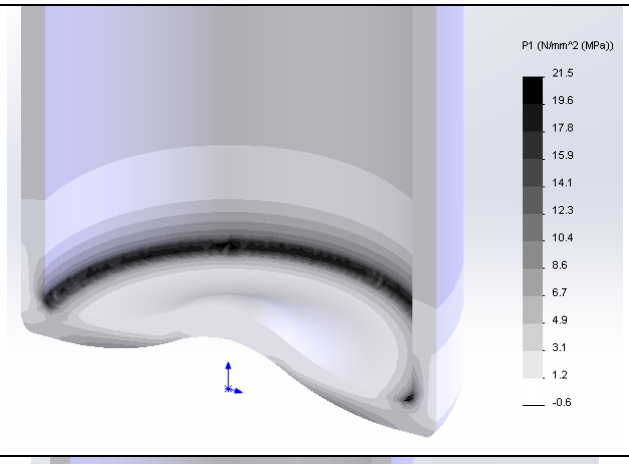
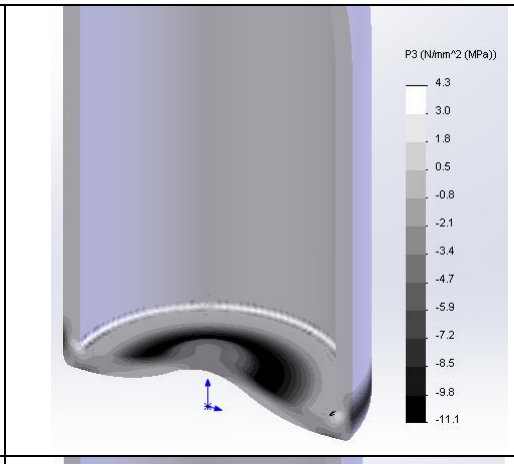
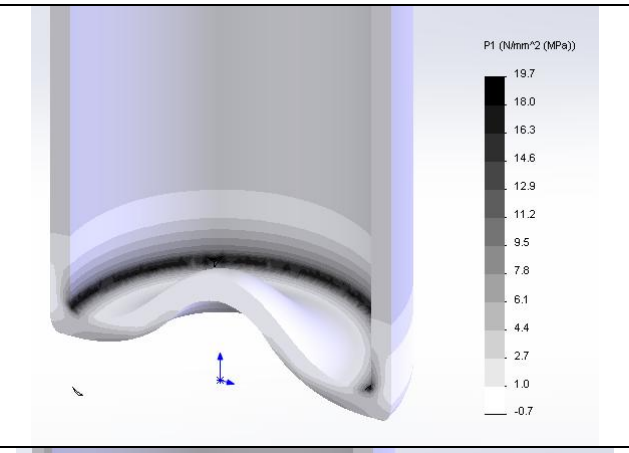
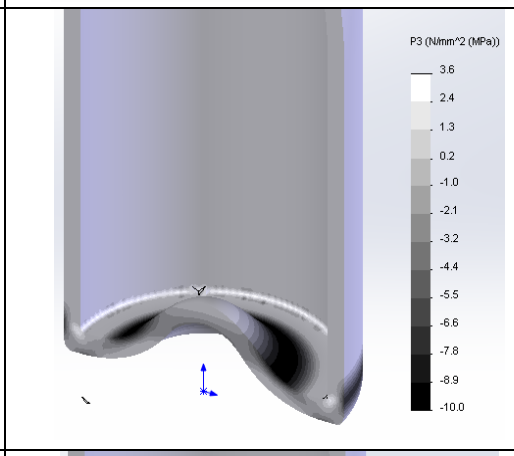
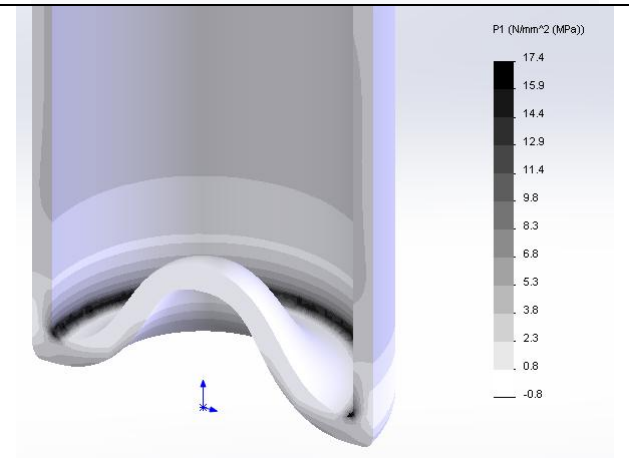
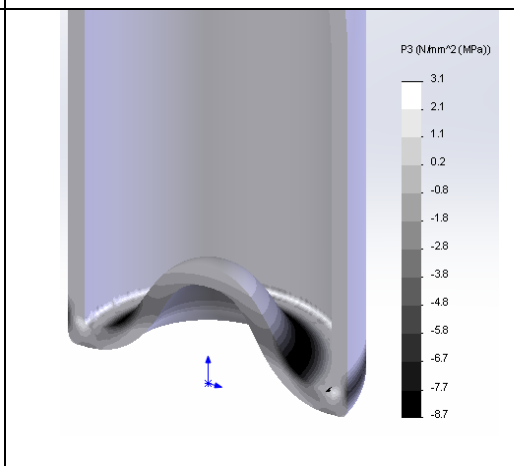
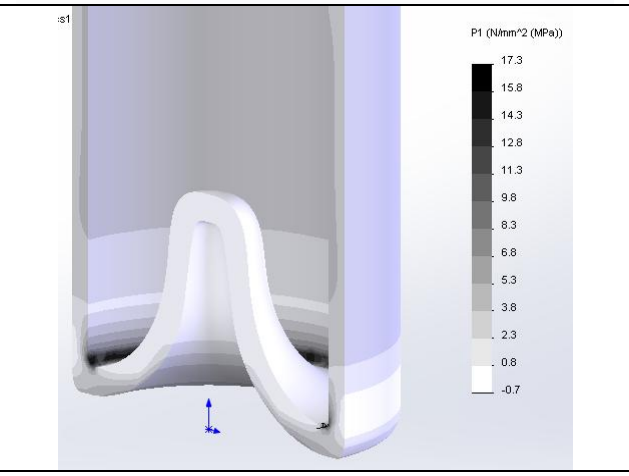
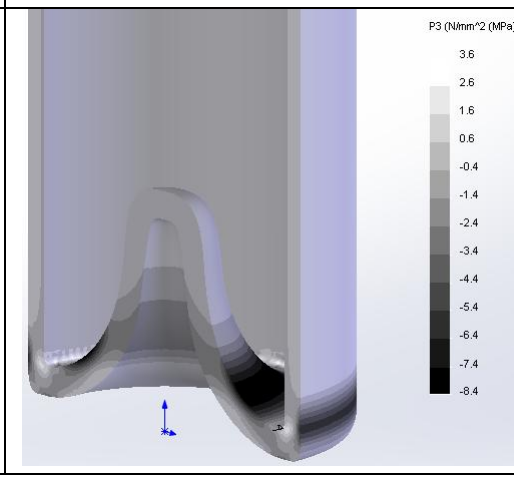
Height at the bottom 10 mm		
Height at the bottom 20 mm		
Height at the bottom 30 mm		
Height at the bottom 50 mm		

Table 3. *Physical quantities of champagne bottles with different punt size under internal pressure of 0,5 MPa*

Bottom punt *H*, mm	First principal stress σ_1^{max} MPa	Third principal stress σ_3^{min} MPa	Mass *m*, g	Total volume *V*, mm^3
0	23,1	- 9,1	839	850 186
10	21,5	-11,1	840	841 277
20	19,7	-10,1	844	829 496
30	17,4	-8,7	861	808 503
50	17,3	-8,4	888	800 804

Along with growing the height of the punt, the mass of the bottle increases because the length of the generatrix increases and more glass material is needed to form the bottle. This mass raising is inevitably but within some range it is compensated by reducing the thickness of the wall and the bottom due to reduction of the maximum tensile stress. If the mass of the bottle with a flat bottom is assumed to be 100%, the mass of the bottle with a punt at the bottom of 30 mm will be 102.6%. But the new shape of the bottom will affect the stress distribution and its maximum value. The maximum value of the first principal stress will decrease by 24.7% , which allows reducing the thickness of the wall and the bottom. This would make the bottle lighter by changing the shape and dimensions. That way, increasing the punt at the bottom of the bottle is beneficial but only up to 30 mm.

Another negative effect of increasing the punt size of the bottom is reducing the capacity of the bottle. The difference between the volume of a bottle with a flat bottom and another one with a punt size of 30 mm is 4,9% when keeping other dimensions unchanged. This reduction of total volume still has no effect on the net capacity of 750 ml (see table 3, the last column), but keeping the standard over all dimensions (height of the bottle and the outer diameter of the cylindrical body) required by the bottling lines, it will affect the size of the gas chamber over bottled champagne wine. Therefore it will affect the filling level and internal pressure in the bottle.

A positive effect of increasing the punt of the bottom is a reduction of dangerous tensile stresses in the transition zone from the bottom to the cylindrical body of the bottle. This, exactly, is the purpose that motivates the search for new forms. Third principal stress by absolute values is less than first principal stress, and cannot be considered dangerous and destructive taking into consideration the properties of glass.

IV. Conclusions

The optimal size of the bottom punt is 30 mm. For bottles with larger punt, maximum tensile stress is reduced with a very small extend (less than 0,06%) while the mass of the bottle increases with 3%. This makes unduly increasing the size of the punt over 30 mm.

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SORPTION CHARACTERISTICS OF PECTIN ISOLATED FROM JERUSALEM ARTICHOKE TUBERS *(HELIANTHUS TUBEROSUS L.)*

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Abstract. *Research was carried out on the pectin content of the tubers of Jerusalem artichoke plants cultivated in Bulgaria. The polysaccharide was extracted. The isolated pectins were analyzed in physical terms: the equilibrium sorption isotherms, belonging to type II in Brunauer's classification, were obtained experimentally. The entire isotherm length demonstrated statistically significant hysteresis. The Henderson and Chung-Pfost models provided adequate isotherm description. The monomolecular moisture content of pectin was within the 7,42 – 7,92% dry basis range, its corresponding water activity value – within the 0,14 – 0,16 range.*

Keywords: Jerusalem artichoke, pectin, sorption characteristics

I. Introduction

Pectins are carbohydrates possessing complex composition and structure. They belong to the acidic branched heteropolysaccrahides. Their major chain is constructed by linearly joined with (1→4)-glycosidic bonds α-D-galactopyranosyluronic acid residues, partially esterified with methanol. α-L-rhamnose with (1→2)-bonds is found among them. Various neutral sugars – D-xylose, D-glucose, D-mannose, L-fructose, etc. – occur in the chain branches [10, 17].

Pectin is a common component of the cell walls of all land plants [18]. Among the basic raw materials used in the manufacture of commercial pectin is apple and citrus fruit peel [12].

Pectin extraction is a multi-stage physico-chemical process taking place under the influence of a number of factors, notably temperature, pH and duration [11]. It has been studied by many researchers. El-Nawawi and Shehata [8] have analyzed the factors bearing upon pectin production during its isolation from orange peel, the results showing that the highest yield is achieved with hydrochloric acid as extractant, at 90 °C, pH 1.7 and 120-minute duration of extraction.

Pagán and Ibarz [13] have studied the production and rheological properties of peach pomace pectin demonstrating that the maximum yield is achieved with 70%-nitric acid, 80°C, pH 1.2 and 60-minute duration. After isolating and analyzing waste apple peel pectins, Virk and Sogi [16] have found out that citric acid is a more efficient extractant than hydrochloric acid. Rehmann et al. [14] have extracted mango peel pectin with the help of sulphuric acid, their results testifying to a maximum yield at 80°C, pH 2.5 and 120-minute duration of extraction. Our previous research features a description of Jerusalem artichoke pectins *(Helianthus tuberosus L.)* [1]. Our results manifest that in tuber pectin extraction maximum yield and purity are achieved with ammonium oxalate as extractant, at 85°C and 45-minute extraction.

In food industry, pectin has a long-established application as a functional food ingredient which is used as a gelling agent and a stabilizer. Scientific literature provides data on the physical and physico-chemical properties of this polysaccharide accounting for its functional and technological characteristics [2, 3]. The equilibrium isotherms of food products show the correlation between equilibrium moisture content and water activity at a given temperature. The sorption isotherms of the product reveal the manner in which water is bound to the solid skeleton. Scientific literature suggests a multitude of empirical and theoretical models for sorption isotherm description [5, 7]. Chen and Morey [7] draw the conclusion that there is no universally applicable model. In general, several models are used, the most adequate of which is opted for on the basis of specific criteria. Model evaluation criteria are usually mean relative error (P, %) and standard deviation (SEM) [4]. Quite a few studies prove that the products whose moisture content corresponds to monomolecular moisture can be stored for long periods of time with no changes to their technological properties [6].

The aim of the present study is the isolation of pectin from Jerusalem artichoke tubers (*Helianthus*

tuberosus L.) and the analysis of its sorption characteristics.

II. Materials and Methods

1. Raw materials

This study is based on the analysis of Jerusalem artichoke tubers collected during the technological maturity of the plant (November, 2012) in three Bulgarian regions: the territory of the city of Stara Zagora, Stara Zagora District (sample №1), the town of Parvomai, Plovdiv District (sample №2) and the town of Vidin, Vidin District (sample №3).

All reagents used in the analysis are p.a.

2. Determination of pectins

The polyuronide content (PUC) was determined via the McCready method which we used earlier [1], as follows:

2.1. Preparation and washing of the raw material.

10 g preliminarily ground plant matter is weighed, to which 100 cm^3 of a 5 %-solution of hydrochloric acid and 70 %-ethanol is added and the mixture is stirred for 1 h with the help of an electromagnetic stirrer. Afterwards, it is filtered in a Büchner funnel and rinsed with 70 %-ethanol first (until a neutral reaction) and then with 96 %-ethanol. The substance is dried at 50°C.

2.2. Polyuronide Content (PUC) determination.

Two 2-gram samples (with a precision of ± 0,0001 g) of the rinsed material are weighed, to each of which 2,00 g of NaCl and 150 cm^3 of distilled water is added. The samples are stirred with an electromagnetic stirrer for 2 h, after which 50 cm^3 of distilled water is added to each of them. Two check samples are prepared. 4-5 drops of Hinton reagent are added to each sample, which is followed by titration with 0,1 n NaOH. 40 cm^3 of 0.1 n NaOH are added to each sample, the samples are then left undisturbed for 2 h, after which 50 cm^3 of 0,1 n H_2SO_4 is added to each of them. The remainder of the acid is titrated with 0,1 n NaOH.

The PUC (%) of the rinsed plant matter is calculated by the following formula:

$$PUC = \frac{(V_1.F.0{,}01761) + (V_2.F.0{,}01901)}{m}.100\%$$

where: V_1 is the volume of NaOH spent in the first titration, cm^3;

V_2 – the volume of NaOH spent in the second titration, cm^3;

F – NaOH factor;

0.01761 – the amount of the non-esterified galacturonic acid residue corresponding to 1 cm^3 of 0.1n NaOH in g;

0.01901 – the amount of the esterified galacturonic acid residue corresponding to 1 cm^3 of 0.1n NaOH in g;

m – sample mass, g.

In order to determine the degree of esterification (DE, %), the following formula is used:

$$DE = \frac{V_2.F}{V_1.F + V_1.F}.100\%$$

3. Extraction of pectins

2000 cm^3 of 85-90°C distilled water containing 18,8 g (0,075 mol/l) of ammonium oxalate is poured on 100 g of the rinsed plant material. The extraction of the mixture continues for 45 min, at 85°C, with regular stirring. It is filtered while hot, the filtrate volume is measured and the filtrate is left to cool at room temperature. 20 cm^3 of concentrated hydrochloric acid and an equal volume of 96 %-ethanol are added. The mixture is stirred well and left undisturbed at room temperature for 2 h. The resultant gel is filtered, rinsed a few times with 70 %-ethanol until the elimination of all chloride ions, then rinsed twice with 96 %-ethanol and dried at 40°C to get constant weight.

4. Analysis of the sorption characteristics of pectins

We used the static gravimetric method recommended for food products [6]. One-gram samples (with a precision of ± 0,005 g) are weighed in weighing dishes. The latter are placed in hygrostats over saturated solutions of seven salts (LiCl, CH_3COOK, $MgCl_2$, K_2CO_3, NaBr, NaCl, KCl) keeping the water activity of the product in the 0,11 – 0,85 range [9]. The hygrostats undergo tempering in a thermostat at 20 ± 0,1°C. When equilibrium is reached (within 20 - 30 days), sample moisture is determined by weighing, the samples being dried for 24 h at 105°C. The experimentally obtained data are average values of the results achieved after triplicate tests.

In order to describe sorption isotherms, we resorted to the two-parameter Chung-Pfost, Halsey, Oswin, and Henderson models [5, 7]:

Chung-Pfost

$$\ln(a_w) = -A\exp(-BM) \quad (1)$$

Halsey

$$a_w = -\exp(AM^B) \quad (2)$$

Oswin

$$M = B\left[\left(\frac{a_w}{1-a_w}\right)\right]^{-C} \quad (3)$$

Henderson

$$\ln(1-a_w) = -AM^B \qquad (4)$$

where M is equilibrium moisture content, % dry basis; a_w – water activity, decimal; *A, B, C* – constants.

To determine the monomolecular moisture content, the wide-known Brunauer-Emmett-Teller (BET) model was used [15], valid for $a_w < 0,5$ [6]:

BET

$$M = \frac{M_m C a_w}{(1-a_w)(1-a_w+C_{aw})} \qquad (5)$$

where: M_m is the monomolecular moisture, % dry basis; C - constant.

III. Results and Discussion

Table 1 presents the results related to the polyuronide content (PUC) and the degree of esterification (DE) of pectins contained in Jerusalem artichoke tubers (*Helianthus tuberosus L*).

Table 1. *Polyuronide content and degree of esterification of pectins in Jerusalem artichoke tubers* (*Helianthus tuberosus L*).

№ in turn	PUC, % a.d.m.	DE, %
Sample №1	14,8	60,7
Sample №2	9,2	63,4
Sample №3	11,9	59,8

a.d.m. – absolute dry matter

It is evident that sample №1 is the richest in pectins. Therefore, this sample was chosen to isolate the polysaccharide from in order to determine its sorption characteristics.

The experimentally obtained pectin sorption isotherms are illustrated in Figure 1. It demonstrates that with low water activity the character of the isotherms is typical of monomolecular adsorption whereas with high water activity it is typical of polymolecular adsorption, i.e. the isotherms possess the characteristic S-shape of Brunauer's II type [6]. Such sorption isotherms are common for many colloid capillary porous products and most foods are such products. The hysteresis effect is statistically significant (ά=0,05) along the entire length of the isotherm and the highest for higher water activity values (over 0,6), reaching 2,5% dry basis. With lower water activity, hysteresis values amount to about 1% dry basis on average.

The coefficients of the linear equations were determined on the basis of the Least Squares method. The coefficient values, mean relative error P and standard deviation SEM of the models from (1) to (4), for desorption and adsorption, respectively, are presented in Tables 2 and 3. The results obtained show that in adsorption the Henderson model is most suitable for sorption isotherm description (the lowest values of P and SEM) while in desorption the most adequate model is that of Chung-Pfost. However, since the differences in the P and SEM values for both models and both processes are minimal, both models can be recommended as equally adequate for the description of pectin sorption isotherms.

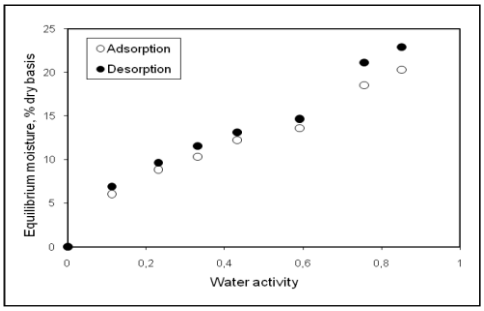

Figure 1. *Equilibrium isotherms of pectin.*

Table 2. *Coefficients of the models (A, B), mean relative error (P,%) and standard deviation (SEM) for desorption.*

Model	*A*	*B*	*P*	*SEM*
Chung-Pfost	6,398093	0,1566	3,36	0,84
Oswin	0,3169	13,85852	4,45	0,94
Halsey	172,2075	2,1395	7,55	1,66
Henderson	0,001587	2,2702	3,43	0,92

Table 3. *Coefficients of the models (A, B), mean relative error (P, %) and standard deviation (SEM) for adsorption.*

Model	*A*	*B*	*P*	*SEM*
Chung-Pfost	6,86956	0,1793	3,79	0,61
Oswin	0,3155	12,5059	4,94	0,84
Halsey	134,5317	-2,1284	8,34	1,69
Henderson	0,001937	2,2838	2,56	0,58

In order to calculate the monomolecular moisture content, equation (5) can be transformed into a linear form:

$$\frac{a_w}{M(1-a_w)} = \frac{1}{MmC} + \frac{(1-C)a_w}{MmC} \qquad (6)$$

On the basis of the slope of the line, using the Least Squares method, one can determine the coefficients of the linear equation (6) and, hence, the monomolecular moisture M_m and the C coefficient. The linear dependence $a_w/[M(1-a_w)] = f(a_w)$, with the experimental data for desorption and adsorption for $a_w < 0,5$, is illustrated in Figure 2. The monomolecular moisture values obtained and the correlation coefficients are given in Table 4.

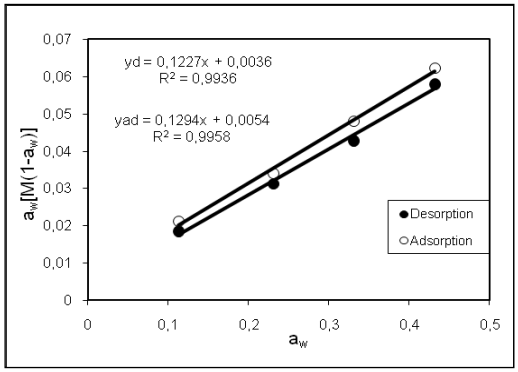

Figure 2. *Dependence* $a_w/[M(1-a_w)] = f(a_w)$ *for pectin*

Table 4. *Monomolecular moisture values (M_m), correlation coefficients (R^2) and water activities corresponding to the monomolecular moisture content (a_{wm})*

Pectin	M_m	R^2	a_{wm}
desorption	7,92	0,9936	0,144
adsorption	7,42	0,9958	0,16

The results demonstrate that the monomolecular moisture content of pectin is from 7.42 to 7.92 % dry basis, the hysteresis effect still occurring, while the value for desorption is higher.

The BET model makes it possible to determine the product's water activity at which it is to be stored in order to preserve its monomolecular moisture:

$$a_{wm} = (\sqrt{C} - 1)/(C - 1) \qquad (7)$$

The results obtained for a_{wm} are given in Table 4. They show that if pectin is to have moisture content approximating monomolecular moisture, it should be stored at water activity within the 0,14–0,16 range.

IV. Conclusion

The pectin content of the three Jerusalem artichoke samples is 14,8; 9,2 and 11,9 % a.d.m., respectively. The experimentally obtained equilibrium sorption isotherms of the pectin isolated from sample №1 belong to type II according to Brunauer's classification. The entire isotherm length manifests statistically significant hysteresis. The Henderson and Chung-Pfost models have been found to be adequate for isotherm description. The monomolecular moisture content of pectin is between 7,42 and 7,92 % dry basis, the corresponding water activity being between 0,14 and 0,16.

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RESEARCH OF MECHATRONIC LINEAR MODULE WITH PNEUMATIC DRIVE BASED ON THE USE OF PROPORTIONAL PRESSURE REGULATORS

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Abstract. *The article deals with the use of mechatronic linear module with pneumatic drive based on the use of proportional pressure regulators for multiple packaging equipment. Designed mathematical model allowed to identify the main kinematic and dynamic parameters of such constructions based on physical and mechanical properties of packaging materials. The previous researches based on the experimental installation of the mechatronic module confirmed the possibility of providing set efforts for retention of packages during their movement in the vertical plane. Obtained results can be used to develop new constructions of multiple packaging equipment.*

Keywords: multiple packaging, retention efforts, mechatronic module, pressure regulator

I. Introduction

Multiple packaging equipment in accordance with the technological process of creating multiple package can be divided into two groups [1,2,3]. Each group is characterized by the trajectory of step-by-step movement of consumer packaging or formed structural units of the multiple packaging [4]. It is assumed that the first group of equipment provides the movement of multiple packaging without any separations during moving surface and the other one is accompanied with such separations.

Technological process graph shown in Figure 1 demonstrates all possible schemes of the technological process performed by the second multiple packaging group.

The technological process of multiple packaging has the following specific sequence: **1.1 - 2.1 - 3.1 - 4.1 - 5.0 - 6.0 - 7.0 - 8.1 - 9.1 - 10.0 - 11.0 - 12.1.** Analysis of technological equipment operations of each group shows that they are common with the use of lifting and lowering mechanisms. The most difficult conditions during the operation of such mechanisms are to provide large static efforts for retention of packages after the stop of output element in a given coordinate. One of the proposed solutions for this problem can be the use of a new mechatronic linear module with pneumatic drive based on the proportional pressure regulators.

Hereafter the term of mechatronic module will be considered as a complete technical system that is represented as a structurally and functionally completed independent product which has automated control system with flexible software of changing technological process of the executive devices operation and feedback as the use of different types

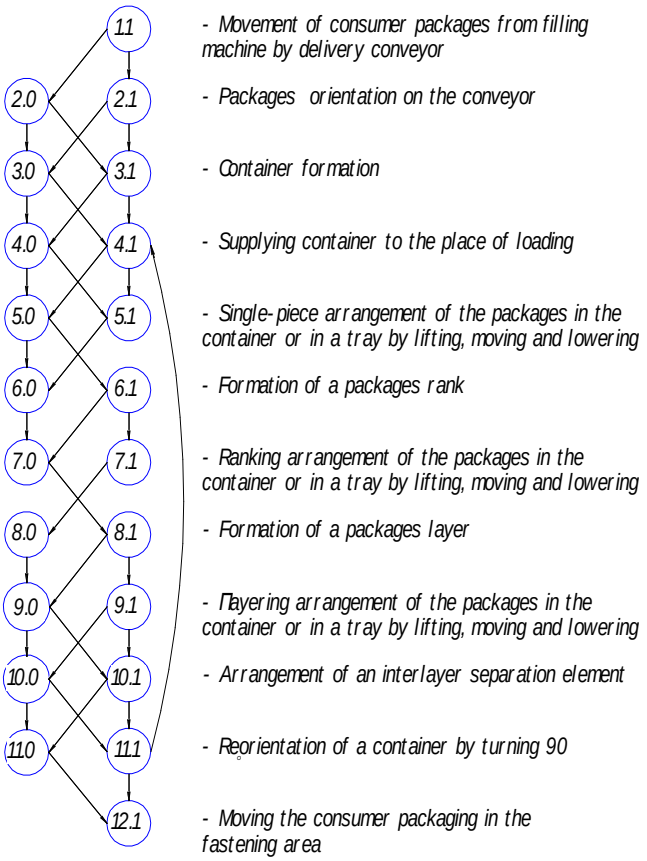

Figure 1. *Structure graph of the technological process of multiple packaging performed by the second equipment group.*

of sensors which provide an opportunity to perceive information about changes in the environment characteristics, is characterized by structurally identified unified channels of the mechanical, power and data connection for synergic connection to other mechatronic modules.

II. Materials and methods

Concept diagram of mechatronic module is shown in Figure 2. It consists of no rod pneumatic cylinder 1 and two proportional pressure regulators 2, each of which is connected to the input and output channels of the pneumatic cylinder and two pressure sensors which provide feedback on the effort. Proportional pressure regulators are designed to convert the control input electrical signal U_y into an output pneumatic one with a variable air pressure value. The main element of the construction of such devices is the isolation valve that moves under the influence of a magnetic field and is able to change the cross-section of pass channel for supplying compressed air. Value of the open channel is represented as the value of the effective area f_e, [5, 6].

Taking into account that the input electrical signal is always positive and varies from *0 to 10 V*, and the work of proportional pressure regulators is not mechanically interconnected, it is need to synchronize changes of instantly effective cavity areas of filling f_e^+ and exhaust f_e^- to implement the law of motion.

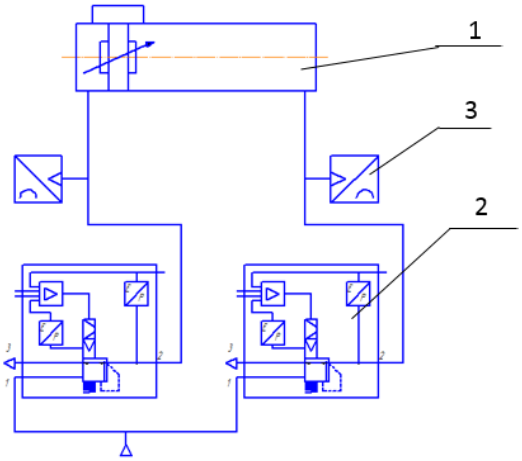

Figure 2. *Concept diagram of mechatronic module with proportional pressure regulators*

One of the possible options of synchronizing the areas f_e^+ and f_e^- can be control of air pressure in the cavities of the pneumatic cylinder as $P_+ \neq P_-$ *at* $f_e^+ \neq f_e^-$. The value of air pressure in the cavity of the pneumatic cylinders depends on the input electrical signal U_y based on the characteristics of its transformation and is defined as [2]:

$$f_e^i = k_{cm} \cdot k_y \cdot U_y^i \qquad (1)$$

where: k_{cm} - coefficient of proportionality; k_y - coefficient of amplification.

It is found [6] that during the system control performance the operation speed of perceiving the control signal by pressure regulator is much greater than the operation speed of perceiving the pneumatic signal by pneumatic cylinders. Therefore the regulator switching time versus the time of air pressure change in pneumatic cylinder will be considered hereinafter as small (instant) and the switching characteristic as static.

Static regulator characteristic can be represented as dependence of pressure changes P_i on the value of the input signal U_y. If two interconnected air pressure regulators are simultaneously used in the control pneumatic cylinders system then static characteristic of their operation as a function of dependance of the changing pressure in piston and rod cavities of the pneumatic cylinder on the input control electrical signal can be represented as a graph in Figure 3.

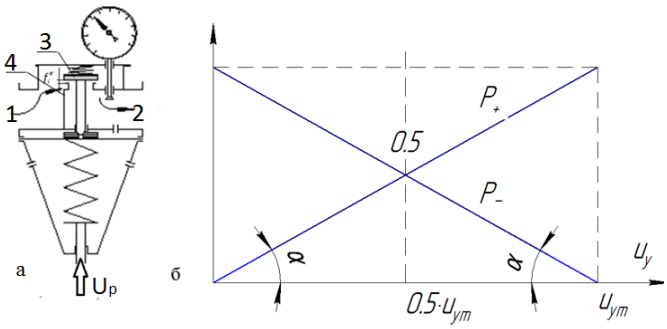

Figure 3. *Description of the proportional pressure regulator: a) isolation valve layout towards frame channels: 1 - power main, 2 - output channel, 3 - isolation valve; 4 - frame; b) static characteristics of two interconnected pressure regulators*

The control signal is represented as a changing voltage within U_y=[0…+U_{ym}]. Designed graph provides a possibility to determine the mode of the pressure regulators operation and describe the control signal for each of them:

- for the air filling cavity in pneumatic cylinder

$$P_+ = \begin{cases} 1 & at \quad U_{y1} = U_{ym}; \\ k_{cm} \cdot U_{y1} & at \quad 0 \le U_{y1} \le U_{ym}; \\ 0 & at \quad U_{y1} = 0; \end{cases} \qquad (2)$$

- for the air output cavity from pneumatic cylinder

$$P_{-}=\begin{cases}1 & at \quad U_{y2}=0;\\ U_{y2}=1-(k_{cm}\cdot U_{y1}) & at \quad 0\le U_{y2}\le U_{ym};\\ 0 & at \quad U_{y2}=U_{ym}\end{cases} \quad (3)$$

Simultaneous implementation of equations (2) and (3) describes the operation of the pneumatic cylinder control system in the mode of positioning. Therefore in the beginning of movement of the pneumatic cylinder rod the control signal for each pressure regulator has a voltage level $U_{y1}=U_{ym};U_{y2}=0$ that provides the pressures volume $P_{+}=1;P_{-}=0$ and describes the beginning of acceleration stage. Transfer to the sustainable movement is characterized by a decrease of the signal value that is given within $0\le U_{yi}\le U_{ym}$. Stage of braking and positioning is characterized by a significant increase of the control signal value in the exhaust cavity $U_{y1}=0;U_{y2}=1$ and by appearance of braking force by increasing the pressure in the cylinder rod cavity $P_{+}=0;P_{-}=1$. Further simultaneous opening of the channels to the level of $f_e^{+}=f_e^{-}=1$ leads to the rod stop rod in set position.

As a result of these changes, we obtain the driving force, given that it is less than the resistance force, that leads to the displacement of pneumatic cylinder rod with kinematic parameters of position, speed and acceleration changes that equal to values

$$x=x_{01}+\Delta x;\ \dot{x}=\Delta\dot{x};\ \ddot{x}=\Delta\ddot{x}, \quad (4)$$

where: $x,\dot{x},\ddot{x}$ - relevant position, speed and acceleration.

The value of pressure in the filling cavity is determined by the equation:

$$p_1\cdot x_{01}=2\cdot K\cdot\frac{f_e^{+}}{S_1}\cdot\varphi_{01}^{+}\cdot k_{cm}\cdot U_y- \\ -f_0\cdot K\cdot\frac{f_e^{+}}{S_1}\cdot\varphi_{01}^{+}\cdot\frac{p_M K_{\varphi 1}}{p_{01}}\cdot p_1-p_{01}\cdot\dot{x}, \quad (5)$$

where: $K_{\varphi 1}=1+K_{01}^{+}p_{01}/(\varphi_{01}^{+}p_M)$; S_1 - area of the piston end face.

If we substitute equation (4) into the formula (5), we will obtain the final equation for determining the effort change that occurs during changing the pressure in the cylinder filling cavity:

$$\dot{F}_1=c_{x1}\cdot(k_{cm}\cdot k_{\beta 1}\cdot U_{y1}-k_{p1}\cdot F_1-\dot{x}), \quad (6)$$

where: $c_{x1}=\frac{p_{01}\cdot S_1}{x_{01}}; k_{\beta 1}=2\cdot x_1^{*};$ (7)

x_1^{*} - constant of cylinder rod speed in the case of switching the distributor valve in end position and in position of full opening of the main channel :

$$x_1^{*}=K\cdot\frac{f_e^{+}\cdot\varphi_{01}^{+}\cdot p_M}{S_1\cdot p_{01}};\ k_{p1}=f_0\cdot\frac{x_1^{*}\cdot k_{\varphi 1}}{S_1\cdot p_{01}}. \quad (8)$$

By similar mathematical transformations we can obtain the equation for determining the resistance force in the exhaust cavity:

$$\dot{F}_2=c_{x2}\cdot(-k_{cm}\cdot k_{\beta 2}\cdot U_{y2}-k_{p2}2F_1+\dot{x}) \quad (9)$$

Obtained effort values (6) and (9) are substituted in equation (2) and after appropriate transformations we obtain the following mathematical observer model with the physical control of the movement parameters of the operating body and the pressure in the pneumatic cylinders cavities [6, 7]:

$$\begin{cases}m\ddot{x}=F_1-F_2-C_{\vartheta}\cdot\dot{x}\pm F;_c\\ \dot{F}_1=c_{x1}\cdot(k_{cm}\cdot k_{\beta 1}\cdot U_{y1}-\bar{k}_{p1}\cdot F_1-\dot{x});\\ \dot{F}_2=c_{x2}\cdot(-k_{\beta 2}\cdot\cdot U_{y2}-\bar{k}_{p2}2F_1+\dot{x});\\ U_{y1}=k_{y1}\cdot U_{p1};\\ U_{y2}=k_{y2}\cdot U_{p2};\\ U_{p1}=k_1\cdot(\bar{x}-x)-k_2\cdot\dot{x}-k_3\cdot\ddot{x};\\ U_{p2}=(1-k_1\cdot(k_{cm}\cdot\bar{x}-x))-k_2\cdot\dot{x}-k_3\cdot\ddot{x}\end{cases} \quad (10)$$

III. Results and discussion

Experimental installation was designed and made to check the adequacy of the proposed control model for the mechatronic linear module with pneumatic drive based on the use of proportional pressure regulators (Figure 4). The element executive unit base and control system were selected in accordance with the results of calculations of mathematical models, generated findings and recommendations and consisted of standard industrial pneumatic elements provided by "Festo" company.

Results of the vertical mechatronic module research during lifting and lowering the intermediate multiple packaging elements are represented as the graphs in Figure 5 and 6.

If we compare the characteristics of lifting and lowering under the same initial conditions, we will make a conclusion that the control system with sufficiently high accuracy reproduces time characteristics of related stages during implementation of a given law of motion. It is found that the average error for the duration of the stages performance is 0,5% and the total time of the movement is the same.

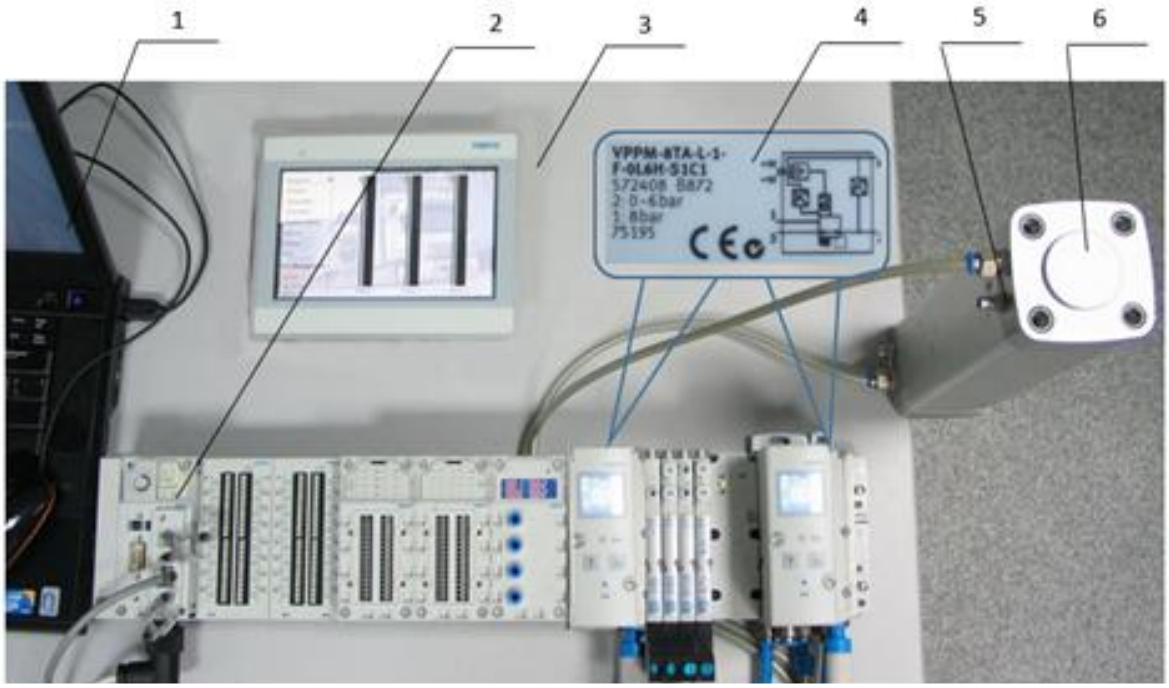

Figure 4. *Experimental installation of the mechatronic linear module with pneumatic drive based on the use of proportional pressure regulators: 1 - system control software, 2 - lower level controller; 3 - operator panel for visualization of data of the kinematic process characteristics; 4 - two pressure regulators with proportional control; 5 - feedback sensors; 6 - double acting pneumatic cylinder*

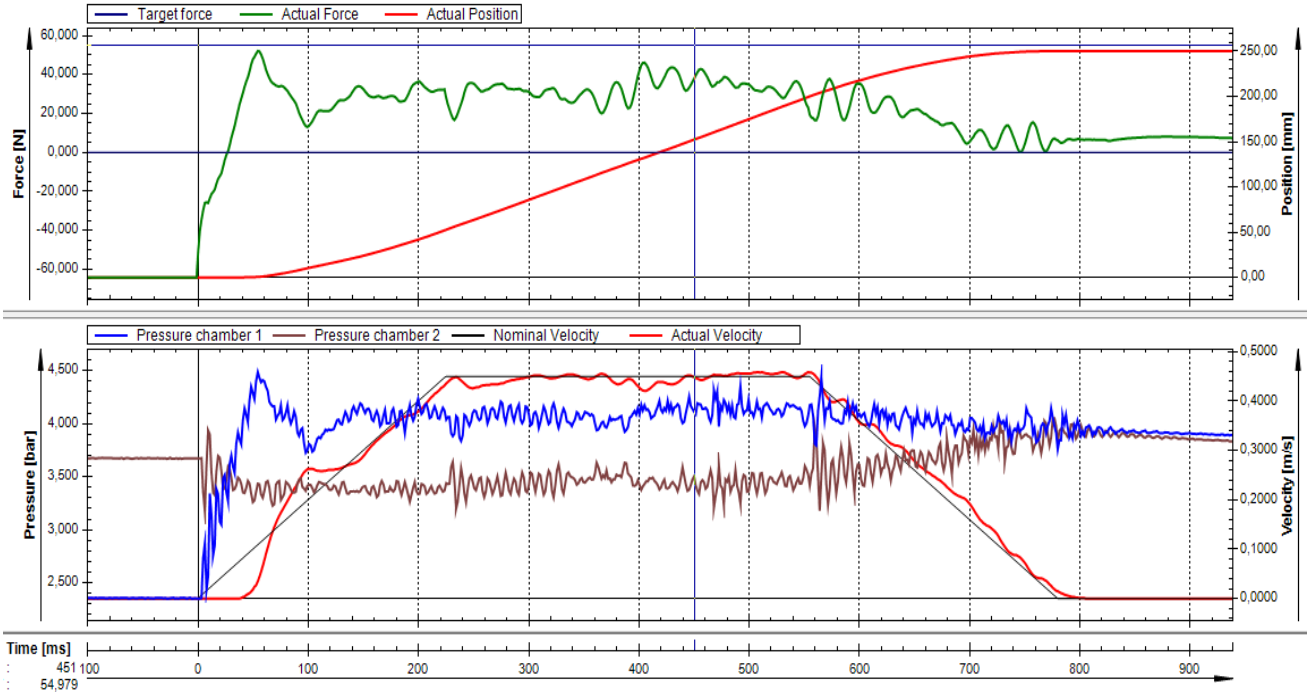

Figure 5. *Kinematic and dynamic characteristics of the packages lowering operation performed by the vertically mechatronic module with pneumatic drive with initial parameters: reduced mass m = 5 kg; step to the stop position on the coordinate s = 250 mm (with maximum step 300 mm); main air pressure P_M = 0,6 MPa*

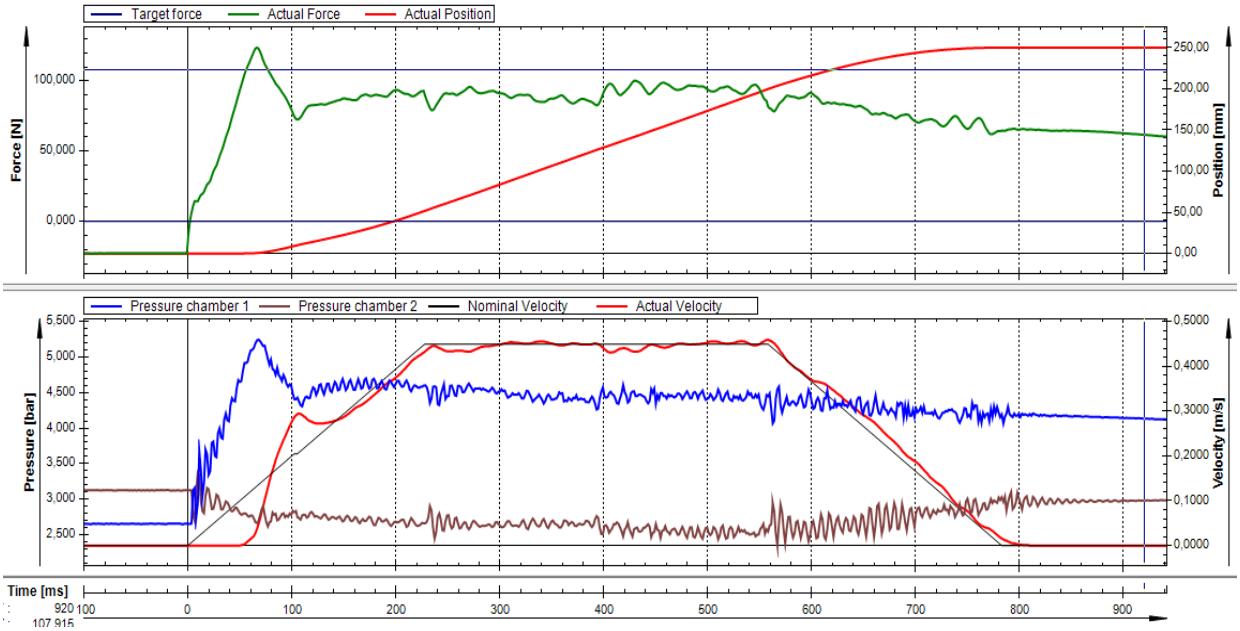

Figure 6. *Kinematic and dynamic characteristics of the packages lifting operation performed by the vertically mechatronic module with pneumatic drive with initial parameters: reduced mass m = 5 kg; step to the stop position on the coordinate s = 250 mm (with maximum step 300 mm); main air pressure P_M = 0,6 MPa*

IV. Conclusions

Based on the research performed it is possible to make the following conclusions:

1. The new proposed structure of the mechatronic module with pneumatic drive for linear motion provides the performance of the technological operations of packaging lifting and lowering in the multiple packaging equipment with sufficiently high functional accuracy;
2. It is found that the use of two pressure regulators with proportional control offers an opportunity to provide a large static efforts retention of reduced mass at the positioning point.
3. Analysis of the results of experimental research on implementation of a given law of motion and positioning accuracy under different operating conditions demonstrated the stability of mechatronic module and its control system. Developed operation algorithm provided the ability to control the retention of packages of various sizes.
4. It is found that proposed construction of the mechatronic module compensates the effect of external static forces on a reduced mass in a dwell position and prevents its positioning coordinates shifting.

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Scheme: BG051PO001-4.3.04 "Development of electronic forms of distance learning in higher education" in OP, Human Resources Development "financed by the European Union through the European Social Fund.
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