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I.M. Fomina[1], T.V. Gavrish[1], K.S. Malikov[1], Yu.V. Ivanova[2], T.I. Viun[2], S.V. Viun[2], K.V. Miasoiedov[2], S.Yu. Bytiak[2], Ye.B. Radzishevska[2]

[1] State Biotechnological University, Kharkiv, Ukraine

[2] Kharkiv National Medical University, Kharkiv, Ukraine

Use of thermoplastically extruded cereal products in nutrition support of patients with chronic pancreatitis and metabolic disorders

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Abstract. ***Background.*** *Chronic pancreatitis (CP) is a complex progressive disease of the pancreas, which is accompanied by significant metabolic disorders, exocrine insufficiency, maldigestion, and malabsorption. Patients with CP often face nutritional deficiencies, which include protein, vitamin, and mineral deficiencies. This leads to weight loss, anemia, and deterioration in the quality of life. One of the key elements in the treatment of such patients is diet therapy aimed at correcting nutrient deficiencies and compensating for impaired digestive system functions. In modern gastroenterological practice, functional food products manufactured using extrusion technology are attracting increasing attention. It allows creating products with high bioavailability, easy digestibility, and an optimal balance of proteins, fats, and carbohydrates. In particular, thermoplastically extruded products based on wheat, buckwheat, and rice cereals, enriched with chicken fillet, carrots, apples, and pumpkin, show high potential in correcting the nutritional status of patients with CP. The purpose of the study was to assess the effectiveness of using thermoplastic extruded products in diet therapy of patients with CP.* ***Materials and methods.*** *The study involved 110 patients, who were divided into two groups: the main (70 participants with CP who received the proposed mixture for enteral nutrition) and the comparison one (40 people with isolated CP who were fed a standard diet). The assessment of nutritional status included determining the level of albumin, hemoglobin, body mass index, as well as the content of pancreatic elastase-1 in feces. For 12 weeks, patients in the main group received extruded products as the main element of the diet.* ***Results.*** *A significant improvement in the nutritional status of the patients was noted. The albumin level increased from 32.1 ± 1.8 g/l to 38.5 ± 2.1 g/l, and hemoglobin from 112 ± 5 g/l to 125 ± 6 g/l. The patients' body mass index increased 1.7 times. All changes were statistically significant. The organoleptic evaluation of the products showed that 91 % of the patients rated them as "tasty" or "very tasty", which ensures a high level of the diet acceptability. In addition, the products are well tolerated, which increases compliance with therapy.* ***Conclusions.*** *The use of thermoplastic extruded products in diet therapy for patients with CP is a promising direction in the treatment of this disease. It allows to ensure the correction of nutritional status, improve the quality of life, and also contribute to reducing the risk of developing complications associated with metabolic disorders.*

Keywords: *chronic pancreatitis; metabolic disorders; extruded products; nutritional support; diet therapy; functional nutrition*

Introduction

Chronic pancreatitis (CP) is a progressive disease of the pancreas, characterized by the development of fibrosis, loss of functional organ tissue, and impaired exocrine and endocrine functions [1]. These pathological changes lead to maldigestion, malabsorption, chronic pain, and serious metabolic disorders that reduce the quality of life of patients and cause a significant medical and social burden [2].

According to current studies, the prevalence of CP in the adult population is 27–50 cases per 100,000 people, and the incidence is increasing annually [3]. The main risk factors are long-term alcohol consumption, smoking, gallstone disease, metabolic syndrome, and genetic predisposition [4].

Patients with CP have progressive exocrine insufficiency, accompanied by a decrease in the level of pancreatic enzymes, including lipase, amylase and trypsin. This causes

Для кореспонденції: В'юн Тетяна Іванівна, доктор філософії з медицини, асистент, кафедра загальної практики — сімейної медицини та внутрішніх хвороб, Харківський національний медичний університет, просп. Науки, 4, м. Харків, 61022, Україна; e-mail: ti.viun@knmu.edu.ua, viun.tatiana@gmail.com; тел.: +380 (66) 915-90-81

For correspondence: Tetiana Viun, PhD in Medicine, Assistant, Department of General Practice — Family Medicine and Internal Diseases, Kharkiv National Medical University, Nauky ave., 4, Kharkiv, 61022, Ukraine; e-mail: ti.viun@knmu.edu.ua, viun.tatiana@gmail.com; phone: +380 (66) 915-90-81

Full list of authors' information is available at the end of the article.

malabsorption of nutrients, especially fats and fat-soluble vitamins (A, D, E, K) [5]. Insufficient intake of these substances into the body leads to weight loss, anemia, osteoporosis, the development of polyhypovitaminosis and impaired immune system function [6].

More than 50 % of patients with CP have clinically significant protein and energy deficiencies, which are associated with an increased risk of complications and mortality [7]. Such patients often develop concomitant diseases, in particular hypertension, which significantly complicates the course of CP due to the activation of oxidative stress and systemic inflammation [8].

Modern approaches to the treatment of CP and metabolic disorders are based on multicomponent therapy, which includes drug correction of exocrine insufficiency, diet therapy, control of chronic pain and prevention of complications [9]. Among them, diet therapy plays a key role, which is aimed at compensating for nutrient deficiencies, improving the functional state of the digestive system and the general well-being of patients [10].

However, traditional approaches to diet therapy have a number of limitations associated with poor digestibility of ordinary foods due to impaired enzymatic activity. One of the innovative solutions is the use of functional food products manufactured using thermoplastic extrusion.

The aim of the study is to develop and evaluate the effectiveness of using thermoplastically extruded products in diet therapy for patients with CP, particularly in conditions of exocrine pancreatic insufficiency.

Materials and methods

The study involved 110 patients with an established diagnosis of CP and metabolic disorders, aged 33 to 45 years, who were divided into two groups: the main group (70 people with CP, who, against the background of standard therapy, received the proposed mixture for enteral nutrition), the comparison group (40 people with CP, whose nutrition was carried out according to dietary table No. 5 according to Pevzner [11]) who were treated in the Department of Liver and Extrahepatic Biliary Surgery of the State Institution "Institute of General and Emergency Surgery of the National Academy of Medical Sciences of Ukraine, Ukraine and the Department of Gastroenterology of the 18th City Clinical Hospital (Kharkiv) in the period from 2023 to 2024. All patients were examined according to a single program developed on the basis of the order of the Ministry of Health of Ukraine dated July 4, 2023 No. 1204 "On Approval of the Unified Clinical Protocol of primary and specialized medical care "Chronic pancreatitis", taking into account the Cambridge classification of chronic pancreatitis. The research methods are ethical and meet international standards. The participants were informed and gave informed consent to participate in the study, which does not pose risks to their health and well-being. The study received approval from the ethics committee.

The age of the patients in the main group ranged from 33 to 45 years with a median of 38 years, the ratio of men to women was 27.1 and 72.9 %, respectively. In the comparison group, the age of the patients ranged from 32 to 43 years with a median of 33 years, and the ratio of men to women was 30 and 70 %, respectively. Thus, the groups are comparable in terms of gender and age.

Together with specialists from the Department of Bakery and Confectionery Technology of the State Biotechnological University (Kharkiv, Ukraine), mixtures for enteral nutrition of patients with CP were developed and tested, taking into account the daily nutritional needs and nutrient malabsorption syndrome. The developed extruded products were made on the basis of wheat, buckwheat and rice cereals with the addition of chicken fillet, carrots, pumpkin and apples. Extrusion technology provided high bioavailability of nutrients and improved organoleptic properties, which was important for patients with digestive disorders.

Given that the level of nutritional status disorders in patients with CP varies depending on the cause of the disease and its severity, and requires an individual approach to correction, the main goal of nutritional support in the treatment of CP is to achieve adequate caloric and nutritional value of food products and the diet as a whole through the products recommended for use.

The nutrition plan during treatment included an individually balanced diet that brings the usual food intake closer to a healthy and balanced nutritional model. Additionally, high-calorie drinks were taken into account, which contribute to an increase in the supply of energy and nutrients. The nutrition plan for patients in the main group included fortified foods and dietary supplements to prevent deficiencies of essential nutrients.

Method of manufacturing mixtures for enteral nutrition. In the process of thermoplastic extrusion, loose raw materials were prepared in the form of a mixture and through a special hole entered the working chamber, where they were mixed while moving along it along a complex trajectory, which leads to an increase in the degree of compression. The degree of compression was determined by the ratio of the area of the working channel to the total area of the exit jets through which the product exits from the matrix. During extrusion, the initial material containing starch was subjected to thermomechanical action, which leads to its destruction and transformation from a state of loose dispersed material into an elastic-viscoplastic mass (gel). This mass is characteristic of highly concentrated starch pastes and denatured proteins.

The following cereals were selected as the main grain product allowed for consumption by patients with pancreatitis: wheat, buckwheat and rice. Chicken fillet, carrots, apples and pumpkin were selected as enriching additives for fortification of traditional cereal products. In order to expand the range of products with different taste and nutritional benefits, the possibility of producing products separately based on each cereal and their mixtures was considered. Namely, product technologies were developed based on the following mixtures: wheat vitamin mixture; wheat protein mixture; buckwheat vitamin mixture; buckwheat protein mixture; rice vitamin mixture; rice protein mixture; combined mixture.

The following research methods were used in the work on creating mixtures.

The amino acid score was determined by the ratio of the amount of each essential amino acid in the protein under study to the amount of the same amino acid in the "ideal protein":

$$Amino\ acid\ score = \frac{mg\ AA\ in\ 1\ g\ of\ the\ tested\ protein}{mg\ of\ AA\ in\ 1\ g\ of\ ideal\ protein} \times 100, \quad (1)$$

where *AA* is any essential amino acid.

The method for determining the biological value of a protein by the adjusted amino acid score taking into account the limiting amino acid and the "apparent" digestibility of the protein — PDCAAS was proposed by FAO/WHO in 1991 according to the formula of G. Schaafsma, 2000.

$$PDCAAS,\ \% = \frac{mg\ of\ limiting\ AA\ in\ 1\ g\ of\ the\ tested\ protein}{mg\ of\ the\ same\ AA\ in\ 1\ g\ of\ ideal\ protein} \times CD \times 100, \quad (2)$$

where *CD* is the coefficient of "apparent" protein digestibility of the product.

DIAAS is a relatively new method recommended by FAO/WHO and used as the main one in assessing the protein value of protein. It assesses the biological value by amino acid score, adjusted for the digestibility of essential amino acids in the ileum, based on measuring the digestibility of each individual essential amino acid in the small intestine, namely in its section — the ileum — as opposed to the traditionally accepted method of determining protein digestibility, which is measured in feces.

$$DIAAS,\ \% = 100 \times \frac{mg\ of\ limiting\ AA\ in\ 1\ g\ of\ the\ tested\ protein}{mg\ of\ the\ same\ AA\ in\ 1\ g\ of\ ideal\ protein} \times CD\ of\ amino\ acid\ in\ the\ ileum. \quad (3)$$

The energy value of extruded products based on wheat cereals was about 340 kcal; buckwheat cereals — 303 kcal; rice cereals — 317 kcal and a mixture of cereals — 322 kcal.

The carbohydrate content was within 60–66 g per 100 g of product and fluctuated significantly with changes in the recipe composition.

An important component is meeting the patient's needs for micronutrients, and it is worth noting that the most common deficiency is that of vitamins D, K and E. Deficiency of water-soluble vitamins is less common. In addition, many patients may have clinical and laboratory indicators of mineral deficiencies, such as magnesium, iron, zinc and selenium [12].

Tables 1 and 2 show the content of vitamins, macro- and microelements in extruded products for nutritional support of patients with CP.

The calculation of the amino acid score of the developed mixtures is given in Table 3.

The formula proposed at the meeting of the FAO Expert Consultative Meeting in 2011 [13] was used as the reference protein.

Patients of the main group consumed the developed mixtures both in dry form and by pouring them with warm water, since warm liquid nutrition is recommended for patients with pancreatitis. The consistency of the product prepared for consumption depended on their personal preferences. When pouring the product with water, it acquired the taste properties of the corresponding porridge with meat or with fruits and vegetables.

The clinical study included the collection of data on the history of the disease, the frequency of exacerbations and concomitant pathologies. All participants signed an informed consent to participate in the study, which was approved by the ethics committee.

The study protocol provided for a baseline assessment of the patients' condition before the start of the use of extruded products, an intervention lasting 30 weeks with a subsequent control examination (on the day 31–32 day of observation).

Table 1. Vitamin content in extruded products for nutritional support of patients with chronic pancreatitis

Nutrient	Unit of measurement	Wheat vitamin mixture	Wheat protein mixture	Buckwheat vitamin mixture	Buckwheat protein mixture	Rice vitamin mixture	Rice protein mixture
Vitamin A, PE	μg	50.99	42.39	50.69	51.35	27.84	21.08
Beta carotene	mg	0.47	0.38	0.47	0.47	0.25	0.19
Vitamin B_1, thiamine	mg	0.40	0.40	0.20	0.21	0.36	0.36
Vitamin B_2, riboflavin	mg	0.30	0.31	0.30	0.31	0.09	0.09
Vitamin B_3	mg	4.90	5.45	5.01	5.57	0.04	0.34
Vitamin B_4, choline	mg	23.36	28.47	53.01	57.89	88.56	90.76
Vitamin B_5, pantothenic acid	mg	0.91	0.99	1.19	1.27	0.64	0.68
Vitamin B_6, pyridoxine	mg	0.40	0.45	0.40	0.44	0.57	0.59
Vitamin B_9, folate	μg	78.11	77.60	42.04	42.11	37.13	37.02
Vitamin E, alpha tocopherol, TE	mg	1.37	1.36	0.10	0.11	0.88	0.88
Vitamin H, biotin	μg					12.45	12.39
Vitamin K, phylloquinone	mg	2.98	2.81	0.62	0.62	0.32	0.24
Vitamin PP, HE	mg					5.50	5.47
Niacin	mg					3.94	3.92
Vitamin C	mg	1.00	0.49	1.10	0.56	0.55	0.25

Table 2. Content of macro- and micronutrients in extruded products

Nutrient	Unit of measurement	Wheat vitamin mixture	Wheat protein mixture	Buckwheat vitamin mixture	Buckwheat protein mixture	Rice vitamin mixture	Rice protein mixture	Composite mixture
Macronutrients								
Potassium, K	mg	407.67	422.24	334.36	353.27	340.34	346.14	373.57
Calcium, Ca	mg	42.17	41.01	19.44	18.73	43.05	42.36	33.97
Silicon, Si	mg					1286.50	1280.49	408.65
Magnesium, Mg	mg	121.22	121.27	214.89	214.08	121.08	121.11	153.29
Sodium, Na	mg	6.19	7.25	15.12	16.55	33.24	33.62	18.46
Sulfur, S	mg	0.22		0.27		62.36	61.96	19.77
Phosphorus, P	mg	375.94	385.24	311.73	322.04	342.29	347.03	350.09
Chlorine, Cl	mg	0.09		0.11		138.03	137.34	43.83
Micronutrients								
Aluminum, Al	μg	4.86		6.04		948.63	941.78	300.56
Boron, B	μg	10.82		13.45		237.81	231.31	73.82
Vanadium, V	μg	0.18		0.22		415.09	413.06	131.82
Iron, Fe	mg	3.48	3.37	2.58	2.46	2.25	2.20	2.69
Iodine, I	μg	0.09		0.11		2.43	2.38	0.76
Cobalt, Co	μg	0.04		0.05		7.18	7.13	2.27
Manganese, Mn	mg	3.15	3.12	1.56	1.54	3.77	3.75	2.78
Copper, Cu	μg	496.22	486.15	585.62	573.69	583.43	578.29	547.07
Molybdenum, Mo	μg	0.27		0.33		27.83	27.57	8.80
Nickel, Ni	μg	0.75		0.93		53.91	53.29	17.01
Rubidium, Rb	μg	2.78		3.46		1.39		
Selenium, Se	μg	69.49	70.26	8.12	9.54	20.76	21.41	33.67
Strontium, Sr	μg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fluorine, F	μg	0.49	0.11	0.58	0.14	83.25	82.67	26.47
Chromium, Cr	μg	0.18		0.22		2.99	2.89	0.92
Zinc, Zn	mg	2.68	2.69	2.35	2.36	1.88	1.89	2.32

Table 3. Characteristics of the protein quality of extruded products studied for the content of essential amino acids

Amino acids	Ideal protein	Wheat vitamin mixture	Wheat protein mixture	Buckwheat vitamin mixture	Buckwheat protein mixture	Rice vitamin mixture	Rice protein mixture	Composite mixture
Lysine	48	65.74	81.83	98.67	109.91	80.94	91.30	92.95
Histidine	16	145.18	155.82	135.52	146.38	158.28	164.92	152.29
Threonine	25	137.98	142.59	144.16	148.25	140.24	143.40	144.32
Tryptophan	6.6	202.51	201.37	203.97	202.83	181.65	182.60	197.73
Methionine + cystine	23	171.36	169.83	123.31	127.37	168.45	167.65	152.04
Phenylalanine + tyrosine	41	211.04	208.31	130.84	137.10	227.37	224.03	183.20
Valine	40	111.63	113.86	118.97	120.30	133.19	133.00	120.73
Isoleucine	30	128.25	132.54	116.95	122.23	124.64	128.08	126.50
Leucine	61	118.47	120.64	95.81	100.31	150.51	149.40	118.77

Table 4. Score evaluation of organoleptic indicators of extruded products

Indicator	Indicator weighting factor	Indicator characteristics	Score
Odor	5	Typical, pronounced	5
		Typical, weakly expressed	4
		Not expressed (absent)	3
		Atypical, slightly altered, but weakly expressed	2
		Atypical, foreign, clearly expressed	1
Color	3	Typical, plain	5
		Typical, plain, slightly darkened or lightened	4
		Typical, not plain	3
		Altered (lightened or darkened)	2
		Atypical (significantly modified)	1
Consistence	4	Typical, homogeneous	5
		Typical, homogeneous, sticky or stiff	4
		Typical, with the presence of unevenly cooked grains	3
		Typical, homogeneous, sticky or hard	2
		Atypical, heterogeneous, sticky, watery	1
Taste	8	Typical, pronounced	5
		Typical, weakly expressed	4
		Not expressed (absent)	3
		Atypical, with a foreign taste	2
		Atypical — stale, expressed quite strongly	1

To assess the condition of the patients, we carried out anthropometry (determination of body weight, body mass index), biochemical blood tests (albumin, hemoglobin levels), as well as determination of the level of pancreatic elastase-1 in feces to assess the exocrine function of the pancreas according to standard methods.

During the organoleptic study of wheat flakes from wheatgrass, the following indicators are determined: taste, color, smell.

The organoleptic evaluation of extruded products was carried out according to the quality indicators given in Table 4.

In the case of score assessment, the evaluation score is multiplied by the weighting factor obtaining a total score in points. Products of excellent quality must have a score of at least 90 points, good — 80–89, satisfactory — 60–79. A product that received a score below 60 points is of unsatisfactory quality.

For statistical data processing, the general-purpose data processing program package "Statistica for Windows" was used.

For data presentation, the median and mean values were used as indicators of the measure of location; standard deviation as an indicator of the measure of dispersion. As a non-parametric comparison method, the Mann-Whitney test (MWT) was used to compare two independent groups, the Wilcoxon test (WT) was used to evaluate the dynamics of indicators, and the t-test was used to compare percentages.

Results

According to our data, consumption of 200 g of extruded products satisfied from 40 to almost 90 % of the daily requirement. The highest level was achieved with the buckwheat protein mixture (Fig. 1).

BCAA are three branched-chain amino acids: leucine, isoleucine, and valine. It is known that branched-chain amino acids, or BCAA, are proteinogenic, meaning they are the main building blocks for protein synthesis. Studies have shown that these amino acids are absorbed more quickly in the gastrointestinal tract and enter the bloodstream than short, unbranched amino acids. This means that protein synthesis with their participation is accelerated. They exist as part of the body's support during mass gain and recovery. The level of BCAA in the developed products is shown on Fig. 2.

The limiting amino acid of grain products used as a basic component is lysine. The use of enriching additives allows to raise the level of lysine in mixtures to 80–90, and in the buckwheat protein mixture the amino acid score for lysine exceeded 100.

It is known that lysine has a great positive effect on the human body, in addition, it improves the functioning of the intestine, restores the balance of microflora, treats dysbiosis, relieves inflammation and helps in the treatment of pancreatitis. Therefore, increasing the level of lysine in the protein composition of the developed products is important.

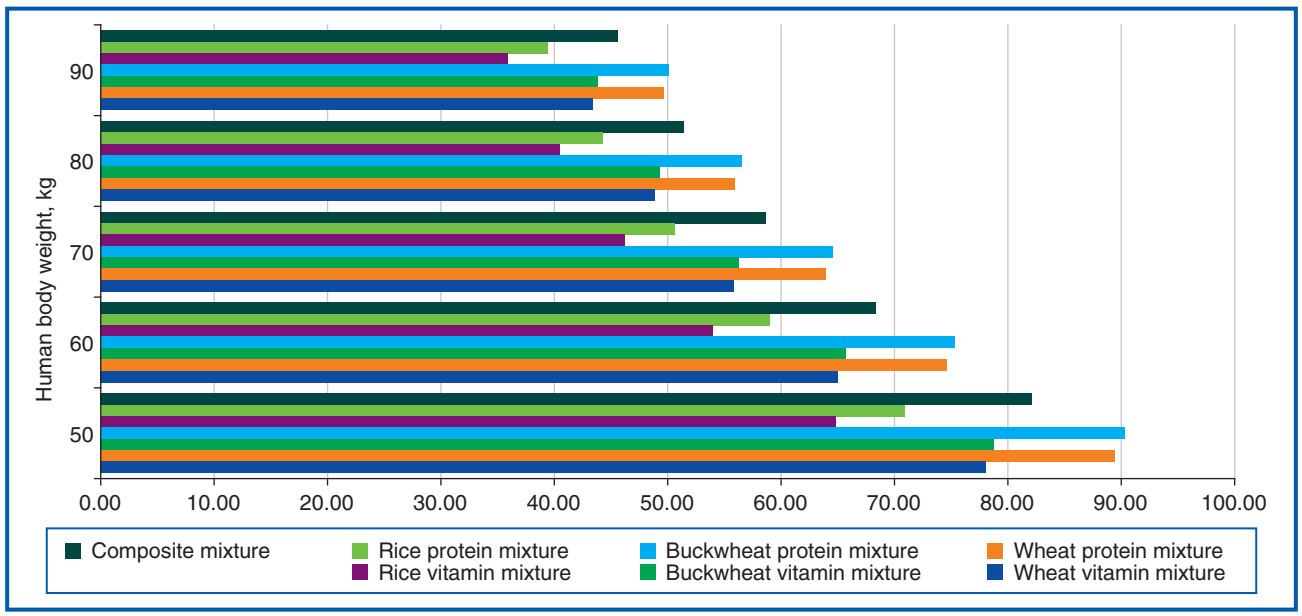

Figure 1. Daily requirement of BCAA for people with different body weights under the condition of consuming 200 g of extruded products per day

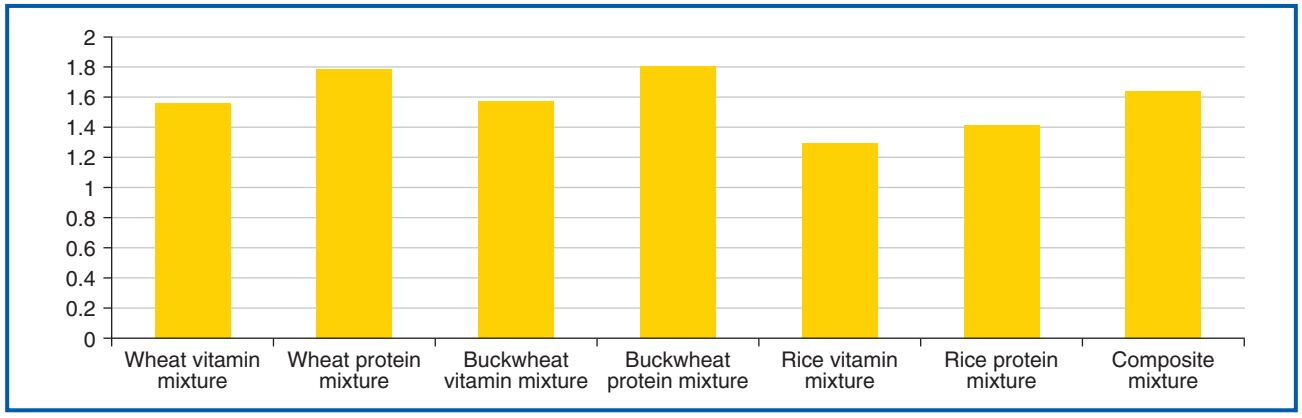

Figure 2. Level of BCAA in developed products (g per 100 g of product)

The study assessed the impact of thermoplastically extruded products on the nutritional status of patients with CP (Table 5).

The values of the pancreatic elastase-1 index in the subjects of the main group and the comparison group were significantly lower than the content of pancreatic elastase-1 in patients of the control group ($p < 0.05$, MWT). The differences in the values of the pancreatic elastase-1 index in patients of the main group and the comparison group did not reach a statistical level.

In general, the majority of patients of the main group and the comparison group in terms of the level of pancreatic elastase-1 in the blood serum had an average degree of severity of excretory insufficiency of the pancreas (43–61.4 and 25–62.5 %, respectively). A mild degree of enzyme synthesis disorder was observed in 27 (38.6 %) and 15 (37.5 %) individuals, respectively.

Patients with severe excretory insufficiency were not involved in the work.

Table 5. Dynamics of laboratory parameters in patients with CP on the background of consumption of extruded products

Laboratory parameters	Patient groups, study terms			
	Main		Comparison	
	Before treatment	Day 31–32	Before treatment	Day 31–32
Blood serum albumin (g/l)	32.1 ± 1.8	38.5 ± 2.0	33.0 ± 1.7	36.2 ± 2.0
Hemoglobin (g/l)	112 ± 5	125 ± 6	114 ± 4	120 ± 5
Pancreatic elastase-1 (μg/g)	113.0 ± 17.7* 113.1 (85–156)*		391.0 ± 63.5* 391.8 (253–507)*	

Note: * — statistically significant differences from the control group (p < 0.05, MWT).

The albumin level in patients of the main group increased 1.2 times from 32.1 ± 1.8 g/l to 38.5 ± 2.1 g/l ($p < 0.01$, WT), while in the comparison group — 1.1 times: from 33.0 ± 1.7 g/l to 36.2 ± 2.0 g/l ($p < 0.01$, WT).

The hemoglobin level in patients of the main group increased 1.1 times from 112 ± 5 g/l to 125 ± 6 g/l ($p < 0.01$, WT), and in the comparison group — 1.05 times: from 114 ± 4 g/l to 120 ± 5 g/l ($p < 0.01$, WT).

The level of pancreatic elastase-1 in feces increased by 15 % in the main group, indicating improved exocrine function. In the comparison group, such changes were less pronounced (7 %, $p < 0.05$, t-test).

Patients in the main group after 30 weeks of using extruded products showed a significant improvement in body weight and body mass index (BMI). BMI increased by 1.8 times, while in the comparison group only by 0.8 times. The changes were statistically significant ($p < 0.05$, WT).

91 % of patients in the main group rated the products as "tasty" or "very tasty", which ensures high compliance with the diet. At the same time, buckwheat and rice mixtures received a score of 90 points, and mixtures made from wheat cereals — 84–86 points.

Discussion

High physiological and technological requirements are imposed on nutritional support products for the treatment of CP. The first group of requirements includes a balanced chemical composition, high nutritional value and easy digestibility of the product. The limiting factor is the narrow range of products recommended for use. Technological requirements include ease of preparation for use. Products manufactured by thermoplastic extrusion meet these requirements. The use of thermoplastic extrusion technology for grain products allows you to obtain a ready-to-use product with adjustable properties that is well digestible.

Nutritional support is an important part of the treatment of CP and aims to ensure sufficient calorie intake, regulate the response to oxidative stress, and prevent catabolic processes during the course of the disease [14]. In the case of the development of hypercatabolic syndrome in patients with CP, energy expenditure can increase by 77–158 % [15]. To calculate nutritional support, it is recommended to take into account the following standards of consumption per 1 kilogram of body weight during the day [14]: energy from 25 to 35 kcal; carbohydrates from 3 to 6 g (at that, the concentration of glucose in the blood serum should not exceed 10 mmol/l); protein from 1.2 to 1.5 g (with possible correction in the case of acute renal or hepatic failure); fats — 2 g (at that, the content of triglycerides in the blood serum should not exceed 12 mmol/l).

The developed mixtures for enteral nutrition fully met these requirements.

The results of the study confirm the effectiveness of thermoplastically extruded products in diet therapy of patients with CP. A significant increase in albumin and hemoglobin levels indicates an improvement in protein-energy status, which is consistent with the results of other studies [1, 15]. An increase in pancreatic elastase-1 levels confirms the positive effect of extruded products on the exocrine function of the pancreas. This may be due to the high bioavailability of proteins and vitamins, which is provided by extrusion technology [16].

In our study, patients in the main group demonstrated better results than patients in the comparison group. This may be explained by a more pronounced effect of the developed products on compensatory mechanisms in combination with CP. According to modern studies, oxidative stress and systemic inflammation with hypertension aggravate nutritional disorders in CP, and the use of products enriched with antioxidants and vitamins helps to reduce them [4, 15].

The organoleptic acceptability of products plays an important role in increasing patients' compliance with diet therapy, which is also confirmed by previous studies [16, 17].

According to current studies, extruded products demonstrate a positive effect on the nutritional status of patients with CP, reduce symptoms of malabsorption and contribute to an increase in energy and endurance levels. In particular, they allow to restore protein and vitamin deficiencies, facilitate digestion processes and are well tolerated by patients [18, 19]. The use of thermoplastically extruded cereal products made from wheat cereals, rice or buckwheat will allow adding a new product to the diet of patients with pancreatitis. This product is almost ready to use, adding warm liquid to the product allows you to quickly prepare warm porridge of the required consistency. This will allow you to use small meals without unnecessary effort and quickly if necessary. Extruded cereal products will be able to satisfy such nutritional requirements of patients with pancreatitis as the consumption of a high-calorie product that is easily digestible. The products are very low in fat, and carbohydrates are represented by dextrinized starch, which is more easily digested and does not belong to simple sugars.

Thermoplastic extrusion technology allows the creation of products that are characterized by: high bioavailability of proteins, vitamins and minerals; easy digestibility due to improved texture and reduced antinutrient content; enrichment with essential nutrients such as amino acids, fiber and antioxidants [20].

Conclusions

The use of thermoplastically extruded products in diet therapy of patients with chronic pancreatitis allows for improved nutritional status, as confirmed by increased albumin and hemoglobin levels.

In patients with CP, the developed products contribute to a more significant improvement in protein-energy status and exocrine pancreatic function compared to patients who followed a standard diet.

The high level of organoleptic acceptability of the products ensures high compliance with diet therapy, which is important for long-term treatment of patients with CP.

Thermoplastically extruded products are an effective and promising component of complex therapy for chronic pancreatitis, especially in the presence of comorbid conditions.

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Information about authors

Iryna Fomina, PhD in Technical Sciences, Associate Professor, Department of Bakery and Confectionery Technology, State Biotechnological University, Kharkiv, Ukraine; e-mail: anirif@ukr.net; phone: +380 (50) 911-81-72; https://orcid.org/0000-0003-2737-1496

Tetiana Gavrish, PhD in Technical Sciences, Associate Professor, Head of the Department of Bakery and Confectionery Technology, State Biotechnological University, Kharkiv, Ukraine; e-mail: gavrishtanya@biotechuniv.edu.ua; phone: +380 (66) 175-89-47; https://orcid.org/0000-0002-5461-8442

Kyrylo Malikov, PhD-student, Department of Bakery and Confectionery Technology, State Biotechnological University, Kharkiv, Ukraine; e-mail: llirik4750@gmail.com; phone: +380 (96) 405-77-27; https://orcid.org/0009-0008-6983-1431

Yuliia Ivanova, MD, DSc, PhD, Professor, Department of Surgery 1, Kharkiv National Medical University, Kharkiv, Ukraine; e-mail: dr.ivanova23@gmail.com; phone: +380 (67) 475-74-29; https://orcid.org/0000-0003-4464-3035

Tetiana Viun, PhD in Medicine, Assistant, Department of General Practice — Family Medicine and Internal Diseases, Kharkiv National Medical University, Kharkiv, Ukraine; e-mail: ti.viun@knmu.edu.ua, viun.tatiana@gmail.com; phone: +380 (66) 915-90-81; https://orcid.org/0000-0002-7862-349X

Serhii Viun, PhD in Medicine, Associate Professor, Department of Surgery 1, Kharkiv National Medical University, Kharkiv, Ukraine; e-mail: serhii.viun@gmail.com; phone: +380 (66) 095-55-54; https://orcid.org/0000-0002-7318-0087

Kyrylo Miasoiedov, PhD in Medicine, Associate Professor, Department of Surgery 1, Kharkiv National Medical University, Kharkiv, Ukraine; e-mail: vonmiasoiedov@gmail.com; https://orcid.org/0000-0002-3878-7713

Serhii Bytiak, PhD in Medicine, Associate Professor, Department of Surgery 1, Kharkiv National Medical University, Kharkiv, Ukraine; e-mail: sergiobit164@gmail.com; phone: +380 (63) 683-49-91; https://orcid.org/0000-0002-6012-2048

Yevheniya Radzishevska, PhD in Physics and Mathematics, Associate Professor, Department of Medical and Biological Physics and Medical Informatics, Kharkiv National Medical University, Kharkiv, Ukraine; e-mail: radzishevska@ukr.net; phone: +380 (67) 799-36-63; https://orcid.org/0000-0001-9149-7689

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Фоміна І.М.[1], Гавриш Т.В.[1], Маліков К.С.[1], Іванова Ю.В.[2], В'юн Т.І.[2], В'юн С.В.[2], М'ясоєдов К.В.[2], Битяк С.Ю.[2], Радзішевська Є.Б.[2]
[1] Державний біотехнологічний університет, м. Харків, Україна
[2] Харківський національний медичний університет, м. Харків, Україна

Використання термопластично екструдованих зернових продуктів у харчовій підтримці хворих на хронічний панкреатит із порушеннями метаболізму

Резюме. ***Актуальність.*** Хронічний панкреатит (ХП) — це складне прогресуюче захворювання підшлункової залози, яке супроводжується значними метаболічними порушеннями, екзокринною недостатністю, мальдигестією та мальабсорбцією. Пацієнти з ХП часто стикаються з нутритивною недостатністю, що включає дефіцит білків, вітамінів і мінералів. Це зумовлює зниження маси тіла, анемію та погіршення якості життя. Одним із ключових елементів лікування таких пацієнтів є дієтотерапія, спрямована на корекцію дефіциту нутрієнтів і компенсацію порушених функцій травної системи. У сучасній гастроентерологічній практиці все більшу увагу привертають функціональні харчові продукти, виготовлені за допомогою екструзійної технології. Вона дозволяє створювати продукти з високою біологічною доступністю, легкою засвоюваністю, оптимальним балансом білків, жирів і вуглеводів. Зокрема, термопластично екструдовані продукти на основі пшеничної, гречаної та рисової круп, збагачені курячим філе, морквою, яблуком і гарбузом, мають високий потенціал у корекції нутритивного статусу хворих на ХП. ***Мета:*** оцінити ефективність використання термопластично екструдованих продуктів у дієтотерапії осіб із ХП. ***Матеріали та методи.*** До дослідження було залучено 110 пацієнтів, яких розподілено на дві групи: основну (70 учасників із ХП, отримували запропоновану суміш для ентерального харчування) та групу порівняння (40 осіб із ізольованим ХП, харчувалися згідно зі стандартною дієтою). Оцінка нутритивного статусу включала визначення рівня альбуміну, гемоглобіну, індексу маси тіла, а також вмісту панкреатичної еластази-1 у калі. Протягом 12 тижнів пацієнти основної групи отримували екструдовані продукти як основний елемент раціону. ***Результати.*** Отримані дані свідчать про значне поліпшення нутритивного статусу. Рівень альбуміну зріс із 32,1 ± 1,8 г/л до 38,5 ± 2,1 г/л, а гемоглобіну — зі 112 ± 5 г/л до 125 ± 6 г/л. Індекс маси тіла пацієнтів збільшився в 1,7 раза. Усі зміни мали статистично значущий характер. Органолептична оцінка продуктів показала, що 91 % учасників оцінили їх як «смачні» або «дуже смачні», що забезпечує високий рівень прийнятності дієти. Екструдовані продукти є ефективним компонентом дієтотерапії осіб із ХП. Їхнє використання дозволяє зменшити прояви мальабсорбції, поліпшити засвоєння білків, вітамінів та мікроелементів. Крім того, продукти добре переносяться пацієнтами, що підвищує прихильність до терапії. ***Висновки.*** Використання термопластично екструдованих продуктів у дієтотерапії пацієнтів із ХП є перспективним напрямом у лікуванні цього захворювання. Воно дозволяє забезпечити корекцію нутритивного статусу, поліпшити якість життя, а також сприяти зниженню ризику ускладнень, пов'язаних із метаболічними порушеннями.

Ключові слова: хронічний панкреатит; метаболічні порушення; екструдовані продукти; нутритивна підтримка; дієтотерапія; функціональне харчування