Journal of Physical Education and Sport ® (JPES), 18 Supplement issue 1, Art 56, pp. 401 - 407, 2018
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Development of new combined sports nutrition products

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Published online: April 30, 2018
(Accepted for publication April 05, 2018)
DOI:10.7752/jpes.2018.s156

Abstract:
The article explores the development of new types of combined sports nutrition products. The results of research on structural and mechanical properties of belip-based minced fish products (BMFP) are presented. The experimental data underwent regression and correlation analyses using the STATISTICA 6.0 software package. Optimal ingredient ratios for BMFP were determined based on the study results.
The aim of the research was to develop new types of combined sports nutrition products with desired structural and mechanical properties using berry pomace as the vitamin and functional supplement. The object of the research was minced cod fillet, which was prepared in compliance with the GOST 50380-92 National Standard. It was .mixed with a curd-fat component (low-fat curd, dairy butter) as a functional ingredient, which was prepared according to the GOST 13264-88 National Standard, as well as red bilberry and cranberry pomace, which was prepared according to our standard specifications.
The recipe mixture optimisation required three stages of research. Stage one: planning and carrying out of the experiment (determination of mixture component weight ratios). Stage two: examination of a mixture model after the experiment and determination of model parameters (regression and correlation analysis). Stage three: determination of component weight ratios for actual production.
Based on the conducted pilot design works, ingredient concentration limits were determined. Acidity, hardness and yield strength were determined for each concentration of composition ingredients. The regression and correlation analysis was performed for the experimental data using the STATISTICA 6.0 software package. Based on the obtained results, the optimal ingredient ratios for BMFP were determined as follows: red bilberry red bilberry pomace : fish component : curd-fat component – 0.93 : 1 : 0.12, and cranberry pomace: fish component : curd-fat component – 0.67 : 1 : 0.12. The ratio of proteins, fats and carbohydrates in the developed minced products is approximately 1 : 0.2 : 0.1. Combination of the developed minced products with other foods makes it possible to have a macronutrient-balanced food ration.
Key words: minced fish mass, berry pomace (juice industry food waste), fish component, curd-fat component, structural and mechanical properties

Introduction

One of main directions in creation of favourable conditions for health maintenance of is healthy lifestyle promotion and physical culture development (Zavydivska et al., 2017). Therewith, special attention is to be given to diet for sportsmen and women because the organism of this category of people requires balanced nutrition due to vigorous exercises (Al-Okbi et al., 2014; Beelen et al., 2010; Gil-Antunano, 2000; McArdle et al., 1996; Newsholme & Leech, 1983). In the course of the training, it is necessary to provide sportspeople with food containing required amounts of amino-acid profile-balanced proteins, carbohydrates, microelements and vitamins in order to maintain normal physiological functions of the organism and muscle mass gaining (Parry-Billings et al., 1992; Sánchez et al., 2011; Colombani & Mettler, 2011). Moreover, the sportspeople's dietary intake is reported to have a role in the improvement of their recovery rate after physical activity of high intensity (Kostopoulos et al., 2017). Therefore, development and creation of functional nutrition products is relevant for sportspeople. Consumed daily, natural origin products have a regulatory effect on the human organism and make it possible to use hidden reserves of the organism during intensive physical loads. Natural origin products might be used as ingredients and nutritional supplements for creation of functional nutrition products (Al-Okbi et al., 2014; Gonzalez & Stevenson, 2012; Rokitzi et al., 1994).

The "belip" poly-functional product containing low-fat curd and cod fillet was developed by the Institute of Nutrition at the Russian Academy of Medical Science (RAMS). The product exhibits high biological

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value, strong lipotropic activity and high gustatory quality. Advantages of belip over other minced fish products are as follows:

1. Belip has a balanced amino-acid-profile as it contains low-fat curd and cod fillet. Fish proteins contain 20 amino-acids, eight of which are essential for the human organism (lysine, methionine, tryptophan, valine, leucine, isoleucine, threonine and phenylalanine). Low-fat curd contains 18% of native proteins (mainly casein) and only 0.6% of fat;
2. It demonstrates high organoleptic properties;
3. It possesses functional properties.

The disadvantage of belip is that it almost completely lacks dietary fibres and water-soluble vitamins necessary for the human organism, especially in the course of vigorous exercises.

Therefore, development of belip-based poly-functional products high in dietary fiber content represents a relevant issue of sports nutrition.

Sports food ration must contain dietary fibres (fibre, hemicellulose and pectin) which are physiologically significant food components preventing a high number of human diseases including those conditioned by environmental deterioration, increase in the number of stress situations and reduction in immunity against pathogenic agents. Dietary fibres represent a low-calorie polysaccharide complex that facilitates chronic intoxication prevention, removes heavy and toxic elements as well as residue of pesticides, radionuclides, nitrates, nitrites thus cleansing the organism, including cleansing from cholesterol, normalises appetite, prevents colon cancer.

Plant material is a source of dietary fibres. Polyphenols, flavins, anthocyans, pectins contained in plant materials bind radioactive isotopes of light and heavy metals and remove them from the human body (Prakhin, 1992).

Vitamins promote resistance to adverse impact of radioactive materials. In particular, vitamins C and P normalise the vessel wall when radioactive materials interfere with normal vascular permeability.

Erythropoiesis is impaired under the influence of radioactive agents and is promoted by folic acid. Radioactive impacts disturb blood clotting ability while vitamin K enhances it. Such vitamins as B2, E and provitamin A (carotin) are also useful under radiation exposure. Fruits containing these protective agents are an important component in radiation damage prevention (Prakhin, 1992).

Berry pomace might be a promising source of dietary fibres, vitamins and microelements. Red bilberry and cranberry pomace contains sugars, dietary fibres, pectin substances, free organic acids (apple lemon, tartaric, benzoic, oxalic, vinegar acids), vitamin C, carotin, vitamins B1, B2, E, P, pectin and tanning substances and microelements: manganese, copper, aluminium, iron and phytoncides.

Therefore, development of recipes and production schemes for the BMFP enriched with berry pomace for sportsmen and women seems relevant.

The purpose of the research is to develop new types of combined nutrition products for sportspeople with predetermined structural and mechanical properties using berry pomace as vitamin and functional supplement. A fish ingredient and a curd-fat component served as the basis for the product.

The main study objectives are exploration of structural and mechanical properties of BMFP and determination of the optimal component concentration (fish, curd-fat and berry components) for BMFP designed for sportspeople.

Material & methods

The object of the research was minced cod fillet prepared in compliance with the GOST 50380-92 National Standard which included a curd-fat component (low-fat curd, dairy butter) prepared according to the GOST 13264-88 National Standard as a functional ingredient as well as red bilberry and cranberry pomace prepared according to our standard specifications.

The task of recipe mixture optimisation was carried out in three stages. Stage one: planning and carrying out of the experiment (determination of mixture component weight ratios). Stage two: examination of a mixture model after the experiment and determination of model parameters (regression and correlation analysis). Stage three: determination of component weight ratios for actual production.

Results

The recipe mixture optimisation required three stages of research. Stage one included planning and carrying out of the experiment.

At this stage, we determined:

1) recipe component concentration limits for the compositions based on pilot design works;
2) acidity, hardness and yield strength of BMFP with different concentrations of components.

The experiment results are presented below in Tables 1 and 2.

It has been determined that the maximum acceptable concentrations of red bilberry pomace and fish component in the compositions are 40% and 60% respectively. Using this concentration, organoleptic properties of BMFP become optimal. The results of organoleptic evaluation are presented in Fig. 1.

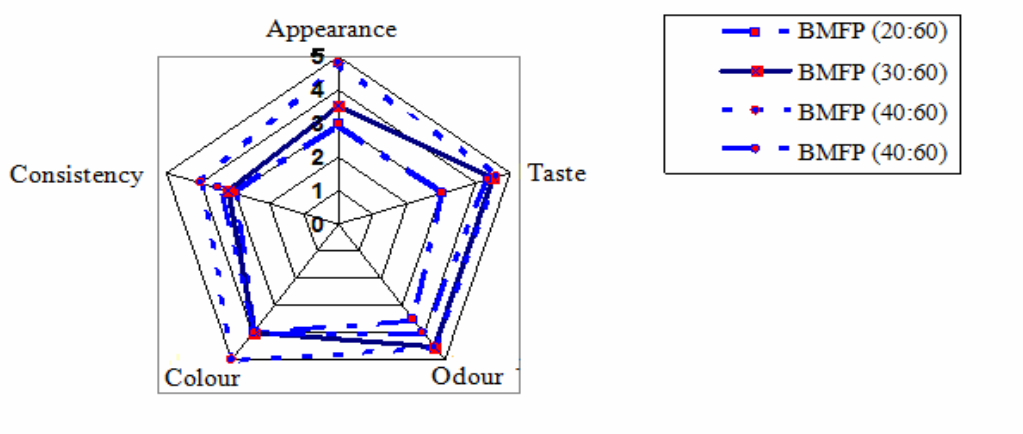

Fig. 1. The results of BMFP organoleptic evaluation

Table 1 Physical and chemical properties of BMFP fish products (composition 1: the experimental data)

Experiment No	x_1	x_2	x_3	$y_{1\,(opt.)}$	$y_{2\,(opt.)}$	$y_{3\,(opt.)}$
1	20	20	2	5.41	286.27	852.38
2	20	40	4	5.41	192.06	569.44
3	20	60	4	5.42	171.75	512.52
4	20	60	6	5.41	170.68	509.48
5	30	40	4	5.36	188.93	563.75
6	30	60	6	5.34	161.73	482.65
7	30	80	6	5.34	107.35	321.04
8	30	80	8	5.34	105.83	316.41
9	40	40	4	5.29	182.93	545.84
10	40	60	4	5.29	140.46	419.51
11	40	80	6	5.3	84.63	253.73
12	40	80	8	5.3	84.69	253.81

composition 1- (fish component – red bilberry pomace – fat-curd component);opt.- optimal; response functions: y_1 – acidity, pH; y_2 –hardness, g/cm^2; y_3 – yield strength, Pa; independent or variable factors: x_1 – berry pomace concentration, %; x_2 – fish component concentration, %; x_3 – fat-curd component concentration, %.

Table 2 Physical and chemical properties of BMFP (composition 2: the experimental data)

Experiment No	x_1	x_2	x_3	$y_{1\,(opt.)}$	$y_{2\,(opt.)}$	$y_{3\,(opt.)}$
1	20	20	2	5.66	260.9	777.96
2	20	40	4	5.67	214.69	640.3
3	20	60	4	5.68	191.43	570.74
4	20	60	6	5.68	190.48	567.97
5	30	40	4	5.49	210.69	628.37
6	30	60	6	5.5	185.41	552.59
7	30	80	6	5.5	127.91	382.07
8	30	80	8	5.5	123.03	367.6
9	40	40	4	5.43	204.69	610.48
10	40	60	4	5.43	171.75	512.53
11	40	60	6	5.44	170.87	509.63
12	40	80	8	5.45	107.35	321.04

composition 2- (fish component – cranberry pomace – fat-curd component);opt.- optimal; response functions: y_1 – acidity, pH; y_2 –hardness, g/cm^2; y_3 – yield strength, Pa; independent or variable factors: x_1 – berry pomace concentration, %; x_2 – fish component concentration, %; x_3 – fat-curd component concentration, %.

Stage two of the study included examination of a mixture model after the experiment and determination of model parameters (regression and correlation analysis). At this the data obtained were processed using the STATISTICA 6.0 software package. The Fisher's F-test was applied for evaluation of regression equation reliability and correlation coefficient significance. The results of linear regression analysis are presented in Table 3.

Table 3 The results of linear regression analysis

	Correlation coefficient (*R*)	**Determination coefficient (R^2)**	**Fisher's F-test (*F*)**
Composition 1			
Acidity, pH	0.988	0.977	118.12*
Hardness, g/cm^2	0.981	0.963	69.93*
Yield strength, Pa	0.98	0,.961	67.05*
Composition 2			
Acidity, pH	0.96	0.92	31.88*
Hardness, g/cm^2	0.982	0.964	72.89*
Yield strength, Pa	0.982	0.965	74.11*

* – the F_{tab} critical level is found using the table (F-distribution: critical values F with freedom degrees v_1 and v_2, the significance level was 5%): F_{tab}=4.08 (Dougherty, 2011).

As our research has proved that $F_{fact} > F_{tab}$, the equations provided below describe the experimental data adequately.

For composition 1:

$$y_1 = 5.53 - 0.0058 \cdot x_1 + 0.00007 \cdot x_2 - 0.0019 \cdot x_3 \quad (1)$$

$$y_2 = 349.65 - 1.68 \cdot x_1 - 2.27 \cdot x_2 - 1.97 \cdot x_3; \quad (2)$$

$$y_3 = 1039.205 - 4.95 \cdot x_1 - 6.74 \cdot x_2 - 5.97 \cdot x_3. \quad (3)$$

For composition 2:

$$y_1 = 5.89 - 0.011 \cdot x_1 - 0.00003 \cdot x_2 - 0.002 \cdot x_3; \quad (4)$$

$$y_2 = 327.88 - 0.92 \cdot x_1 - 1.8 \cdot x_2 - 3.55 \cdot x_3; \quad (5)$$

$$y_3 = 976.97 - 2.73 \cdot x_1 - 5.36 \cdot x_2 - 10.56 \cdot x_3. \quad (6)$$

Table 4 presents the results of correlation analysis demonstrating a strong correlation between variable factors and response functions.

Table 4 Correlation analysis of variable factors influence on response functions

Response functions	Pair correlation coefficient		
	Berry pomace, x_1	**Fish component, x_2**	**Curd-fat component, x_3**
Composition 1			
Acidity, pH	- 0.98	- 0.44	- 0.38
Hardness, g/cm^2	- 0.612	- 0.95	- 0.84
Yield strength, Pa	- 0.61	- 0.95	- 0.84
Composition 2			
Acidity, pH	- 0.96	- 0.36	- 0.37
Hardness, g/cm^2	- 0.49	- 0.96	- 0.89
Yield strength, Pa	- 0.49	- 0.96	- 0.89

Notes:

- composition 1- (fish component – red bilberry pomace – fat-curd component);
- composition 2- (fish component – cranberry pomace – fat-curd component);
- independent or variable factors: x_1 – berry pomace concentration, %; x_2 – fish component concentration, %; x_3 – fat-curd component concentration, %.

It is evident from equations, graphs and calculated data that desired functions y_1, y_2, y_3 adequately describing the process of change in structural and mechanical properties of BMFP are approximated by straight lines. Their analysis made it possible to reveal the following consistent patterns:

1) Hardness of the compositions decreases with increasing weight ratio of the fish component (r1= -0.95 , r2= -0.96) and the curd-fat component (r1= -0.84 , r2= -0.89);

2) Yield strength is largely influenced by increase in concentration of the fish component (r1= -0.95, r2= 0.96) and the curd-fat component (r1= -0.84 , r2= -0.89);

3) Acidity of the compositions mainly depends on berry pomace concentration (r1= -0.98, r2= -0.96).

The results of the experimental data obtained and their analysis confirm the validity of the assumption that there is structural compatibility between fish material and pomace of red bilberry and cranberry. Decrease in acidity of the fish-curd mass, proximity of environment pH to 5.0 leads to increase in water-binding power of proteins and

improvement in structural and mechanical properties of the fish-curd mass (decrease in hardness and yield strength).

Stage three involved determination of component weight ratios for actual production. Dependence of acidity and structural-mechanical property alteration on concentration of composition recipe ingredients is of linear character. The STATISTICA 6.0 software package was applied in order to determine optimal ratios of components in the compositions. Search for the y_1, y_2, y_3 functions optimum was conducted based on the obtained regression equations. The following minimal and maximal concentrations of components x_1, x_2, x_3 were determined based on organoleptic properties:

$$10 \le x_1 \le 40,$$
$$20 \le x_2 \le 60,$$
$$2 \le x_3 \le 8.$$

Limits of functions determined by organoleptic properties and requirements imposed on acidity and structural-mechanical properties of BMFP. For the suggested compositions, inequalities were as follows:

$$5.3 \le y_1 \le 5.5,$$
$$160 \le y_2 \le 200,$$
$$480 \le y_3 \le 560.$$

The optimal concentration of each component in the compositions was determined by finding the arithmetic mean. The obtained results are presented in Table 5.

Table 5 Optimal concentrations of components in the compositions

No. of the composition	Search for the minimum of the y_n functions	Optimal concentrations of components, %			Value of the function $y(x_1, x_2, x_3)$
		Berry pomace, x_1	Fish component, x_2	Curd-fat component, x_3	
1	y_1	39.241	50.3	2	**5.289**
	y_2	40	47.624	7.281	**160**
	y_3	40	30	6.737	**476.216**
	x (mean value)	**39.747**	**42.6**	**5.3**	-
2	y_1	40	60	8	**5.432**
	y_2	40	57.044	8	**160.001**
	y_3	40	60	6.266	**480.001**
	x (mean value)	**40**	**59**	**7.4**	-

composition 1-(fish component – red bilberry pomace – fat-curd component); composition 2- (fish component – cranberry pomace – fat-curd component); response functions: y_1 – acidity, pH; y_2 –hardness, g/cm^2; y_3 – yield strength, Pa independent or variable factors: x_1 – berry pomace concentration, %; x_2 – fish component concentration, %; x_3 – fat-curd component concentration, %.

The following values were obtained for composition 1: $x_1 = 39.747$, $x_2 = 32.54$, $x_3 = 5.3$ % in case of $y_1 = 5.289$ pH, $y_2 = 160$ g/cm^2, $y_3 = 476.216$ Pa; and for composition 2: $x_1 = 40$, $x_2 = 59$, $x_3 = 7.4$% under condition that $y_1 = 5.432$ pH, $y_2 = 160.001$ g/cm^2, $y_3 = 480.001$ Pa.

The results of optimisation have proved that for the composition red bilberry pomace : fish component : curd-fat component it is appropriate to use the ratio 0.93 : 1 : 0.12, while for the composition cranberry pomace: fish component : curd-fat component the ratio should be 0.67 : 1 : 0.12.

Chemical composition of BMFP is presented in Fig. 2. The ratio of proteins, fats and carbohydrates is 1 : 0.2 : 0.1 respectively.

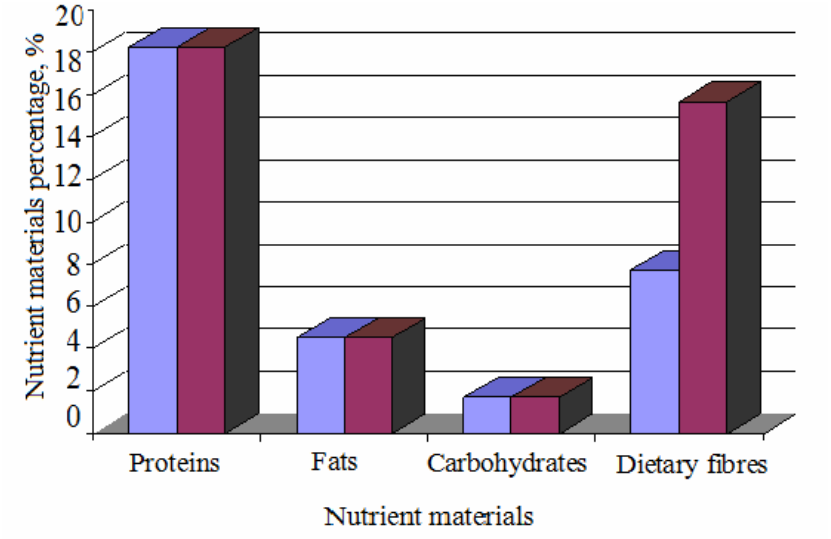

Fig. 2. Chemical composition of BMFP, 100 g

The percentage of satisfaction of the essential amino-acids needs (amino-acid score) by 100 g of BMFP is presented in Fig. 3.

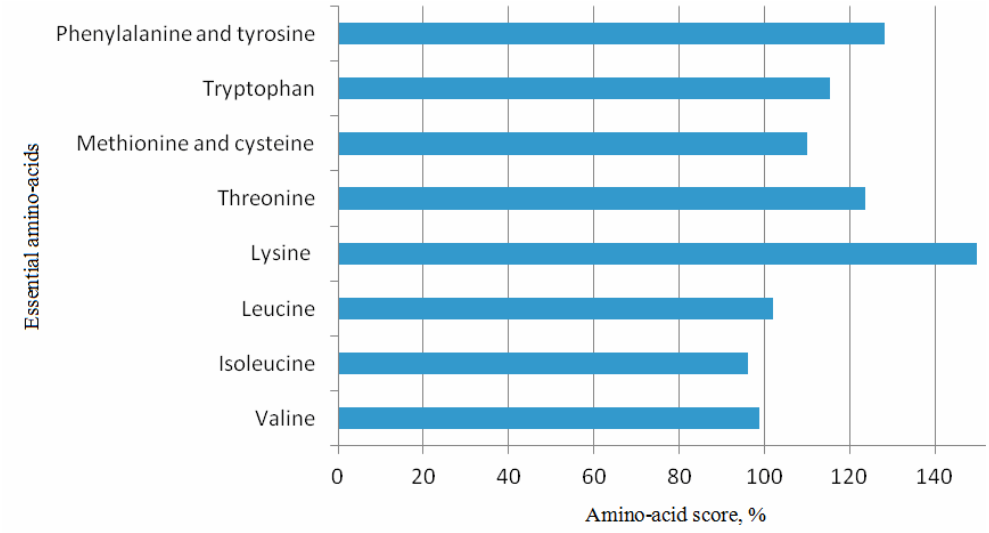

Fig. 3. Amino-acid score of BMFP

Discussion

Many authors emphasise the necessity to include protein products balanced in their amino-acid content into food rations of sportspeople (Parry-Billings et al., 1992; Sánchez et al., 2011; Colombani & Mettler, 2011). Inclusion of the described minced products into food rations for sportsmen and women makes it possible to enrich their nutrition with proteins. In particular, 100g of the product can satisfy daily valine requirement of the organism by 98.9%, daily isoleucine requirement by 96.15%, daily leucine requirement by 102%, daily lysine requirement by 149.85%, daily threonine requirement by 123.62%, daily methionine and cysteine requirement by 109.89%, daily tryptophan requirement by 115.38%, daily phenylalanine and tyrosine requirement by 128.2%.

The research is in compliance with the statement that a sufficient level of energy balance must be maintained in rations of sportspeople which is evident from works of other authors (Gil-Antuñano, 2000; Newsholme & Leech, 1983; Gonzalez & Stevenson, 2012; McArdle et al., 1996; Rokitzi et al., 1994). The developed belip-based minced fish products are a source of dietary fibres that are known to improve intestinal motility and increase metabolism of the organism. Therefore, inclusion of these minced products into food rations for sportsmen and women makes it possible to enrich sportspeople's diet with proteins and dietary fibres.

Describing the process of designing a nutrition and energy valuable functional product with optimal structural-mechanical and organoleptic properties for sportspeople, our research will facilitate a solution to the problem of creation of innovational functional products for sportsmen and women.

Conclusions

Optimal ratios of components in the developed compositions were determined: red bilberry pomace : fish component : curd-fat component – 0.93 : 1 : 0.12, and cranberry pomace: fish component : curd-fat component – 0.67 : 1 : 0.12.

The ratio of proteins, fats and carbohydrates in the developed minced products is approximately 1 : 0.2 : 0.1. Combination of the developed minced products with other foods makes it possible to have a macronutrient-balanced food ration.

Conflicts of interest - The authors have no conflicts of interest to declare.

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