

Conference Paper

Development of An Extruded Potato Snack Using Recycled Materials

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Abstract

The study is aimed at solving the problem of snacks deficiency corresponding to the concept of a balanced diet. Snacks were made using rational process parameters using fish powder obtained from the fillet waste of protein-rich salmon and malt grains rich in dietary fiber. The composition of the recipe mixture was optimized through calculation and a series of experiments. In investigate took as calculated variables the starch and fat content in the recipe mixture and the biological value; as response variables, organoleptic properties and expansion coefficient. The result was an extruded snack, consisting of 79% of crushed dried potatoes, of 8% of fish powder and of 12% of malt grains, which, in comparison with similar snacks, has a higher biological value of 83%, an increased protein content of 14.5% and a dietary fiber value of 8.4 %, a reduced fat content of 1% and a reduced energy value of 340 kcal. The analysis of the quality indicators of the snack confirmed that this product satisfies the requirements for snacks in terms of physicochemical, organoleptic, microbiological and safety indicators. The developed potato extruded snack is targeted at different population groups and is a healthier alternative to potato chips.

Keywords: snacks, thermoplastic extrusion, potato chips, malt grains, edible fish processing offals

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1. Introduction

Over the past 15 years, there has been a steady increase in snack consumption. This trend is due to the accelerated pace of life of the urban population. Snacks are used for consumption on the go, saving time, as an addition to main dishes, as well as to low-alcohol and non-alcoholic drinks. The main criteria that consumers impose to snacks are attractive organoleptic properties, ability to quickly quench hunger and ease of consumption. The popularization of healthy lifestyles has led to an increase in the importance of nutritional value, as evidenced by the growing demand of food consumers for a higher content of protein and of dietary fiber [1].

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The researchers [2, 3, 5, 8, 11, 13] note in the snacks on the market that they are high in fat and salt, high in calories, they are characterized by biological poverty and an unbalanced composition. Regular consumption of such products contributes to various deficiencies leading to the development of nutritional diseases. Can solve this problem by finalizing the recipe for snacks so that they still meet the requirements of high attractiveness for the consumer, but contain ingredients that make them more complete.

The main share of consumption worldwide comes to chips and extrudates. This is due to the gastronomic properties, the possibility of wide variation in assortment and price. According to analysts, this trend will continue in the next decade, while the proportion of extrudates will grow rapidly.

The main raw materials for extruded expanded snacks are plant materials with high starch content (more than 50%), for potato extrudates they are potato starch, potato flakes, corn flour and mixtures thereof. The process of extrusion of potatoes has not been studied much in spite of the fact that it is one of the most widely cultivated starch crops. The studies of potato extrusion are presented in the works of StojceskaV. [2], Onwulata C.I. [3], Nath A. [4], Nayk B. [5], Ostrikov A.N. [6].

The use of fish raw materials for the enrichment of extrudates from potatoes makes it possible to increase the biological value of snacks, since fish proteins are complete and differ in the composition of exogenous amino acids. As the demand for fish products is steadily growing, a large offal amount appears in the industry. Complex processing plants are effectively operating in Iceland, Norway, Finland, and Japan, they are absent in Russia and a number of other countries, and the recycling of offal is irrational. Thus, it is important to reduce the amount of recyclable offal by increasing the depth of processing of fish raw materials using new technologies [7]. Offal generation during processing of fish raw materials depends on the adopted technological scheme, the range of products, the equipment used, on the size type and quality of fish, on the fishing season. The main product for processing large fish, such as salmon, is the fillet, from which most of the fish products are produced. When filleting, a sufficient amount of meat is formed in the form of offal, for example, bellies, flanks, growths, napes, cuts on the ridges. Also, when processing fish with mechanical damage, damaged areas are removed, as a result of which additional meat cuts and non-standard pieces are formed. These offals are not inferior in nutritional value in comparison with the main muscle mass of fish and in terms of quality indicators meet the requirements for the production of food products [8]. Moreover, these wastes have a low cost. Particular care must be taken to use such offal in processing of salmon fish, as the most valuable with high fat content. A number of scientists have suggested the processing of salmon meat

offal into soup sets, canned food, preserves, frozen convenience foods, fish pastes and mousses, fish oil, fish hydrolysates and concentrates [9].

Introduction of malt grains into the snack seems to be promising as a source of dietary fiber. It has long been believed that malt grains have no value for human nutrition, but their important role of dietary fiber in maintaining the body's vital activity has been proven. When considering malt grains, it is mainly used for the production of bakery, confectionery, meat and fish products.

In studies [10--13], which confirmed the prospects and relevance of this area, developed snacks, which included offals of processing hydrobionts and ones from brewing industries. In [10], technology for fish crackers from minced tilapia, corn flour and starch was obtained, in [11] -- functional extruded snacks using shrimp powder, in [12] -- extruded fish and corn snacks, in [13] -- malt grains were added to the extruded snacks.

Thus, in the current economic and social conditions of the modern world, the replacement of potato chips with extruded snacks with high nutritional value is relevant. The relevance of the study is to create new extruded potato snacks that would reduce the level of protein and dietary fiber deficiency in the diets of megacities, as well as expand the range of products while reducing the cost of snacks through the use of offals from fish processing and brewing industries.

The purpose of the study is scientific substantiation of the choice of the recipe composition for the production of expanded extruded potato snacks enriched with proteins and with dietary fiber, analysis of the quality of the finished product.

2. Methods and Equipment

The choice of components of the recipe mixture was based on factors of the prevalence, cost and traditionality of raw materials, the possibility of obtaining the finished product with a composition corresponding to the balanced nutrition formula, with maximum biological value and expected organoleptic characteristics.

When developing the formulation, the restrictions imposed by the thermoplastic extrusion process were taken into account in order to obtain expanded extrudates with a developed porous structure and a sufficient expansion ratio. The expansion ratio is one of the main qualitative indicators of expanded snacks; it determines the depth of the physicochemical transformations of nutrients during the extrusion of starch-containing raw materials. The extrusion process limits the moisture content of the recipe mixture (10-20%), the starch content (more than 50%) and fat (up to 5%). At higher humidity, the amount of applied thermal energy is not enough for explosive evaporation of moisture

from starch grains, at lower humidity the amount of steam formed is not enough to break the starch grains in full. Thus, in both cases, the porosity of the snack is poorly developed and unevenly distributed. When the starch content is less than 50%, a fibrous structure is formed, which is determined by the transformation of the protein globular structure into the fibrillar one. When the fat content is exceeds 5%, a decrease in the expansion coefficient and in the shelf life of the extrudates is observed [6, 14].

Potato was chosen as the main ingredient, as a traditional culture for the production of chips with sufficient starch content (66.6%). Potatoes are grown in the USA, China, Russia, India and Poland. Potato drying is necessary due to the restrictions imposed by the hot extrusion process on the moisture content of raw materials. Using dried potatoes as the only component allows getting snacks with good organoleptic characteristics, but their nutritional value is small, since dried potato contains only 8% of protein and 5% of dietary fiber.

Enriching potato snacks with proteins from salmon is a good option, as fish proteins have the highest digestibility and the combination of potato and fish flavors is popular. Salmon fish are promising for this, since they have high biological value, are processed mainly on fillets and are difficult to store due to high fat content. Using salmon meat filleting waste is economically beneficial for Russia, Norway, Chile, Great Britain, the USA, Denmark and other countries involved in the extraction and processing of salmon fish. Salmon meat wastes contain all essential amino acids, essential omega-3 fatty acids (eicosapentaenoic and docosahexanoic), fat-soluble vitamins A and D, micro and macro elements in human-friendly ratios. For extrusion, salmon fish waste was processed into powder, which increased the shelf life of fish raw materials.

An increase in the content of dietary fiber in potato snacks is rational due to dry malt grains, which are undeservedly little used for the production of snacks in particular. The chemical composition of the malt grains depends on the quality of the malt, the amount of unmalted raw materials, as well as on the type of beer made. The amount of beer grains formed depends on the quality and on the assortment of rubbed grain products, used mash filtering technology and methods, and grain unloading methods. Dry malt grains meet the requirements of the extrusion process for the properties of raw materials, have a sufficiently high nutritional value, meet the safety requirements for food raw materials and are well transportable.

Thus, the recipe mixture for the production of extruded potato snacks consists of crushed dried potatoes, fish powder from growths, flanks, napes, fish bellies, cuts from ridges, slices and non-standard pieces of salmon and dry malt grains. The chemical

composition and content of the essential amino acids of the recipe components are taken from the literature [15].

The composition of the extruded mixture was developed according to the standard method described in [6]. According to the calculation results, the percentage ratio of ingredients is determined at which the maximum biological value is achieved while satisfying the requirements for the extrusion process. After the calculation, a series of experiments is carried out, during which the quality indicators of the resulting snack are evaluated. The technique used allows scientifically substantiating the choice of components of the recipe mixture and calculating their percentage ratio taking into account optimization criteria. In a series of experiments, selected ingredients were used. The resulting extrudates were analyzed as for their organoleptic properties, biological value (BV) and physical quality indicators (bulk density (ρ), expansion ratio (S)).

The preparation of the recipe is described below. Defrosted fish wastes were ground into minced meat. The minced meat was dried in a thin layer in convection dryer at a constant process temperature of 333 K to a final moisture content of 10-12%. The malt grains were sieved. Potato tubers were washed and peeled, blanched to prevent starch from reaching the surface, and pulverized. The resulting chips were pressed and dried in convection dryer at a constant temperature of 328 K. The prepared raw materials were loaded into the mixer in a predetermined percentage ratio and mixed, after which the required amount of water was added and mixing continued until the moisture was uniformly distributed in the mixture. Then the resulting mixture was loaded into a preheated extruder. The first portion of the obtained extrudate was rejected due to an unstable extrusion mode; after 60 seconds, the operating mode was established in which samples were taken in three times with a break of 300 seconds.

Mixtures were processed in a single screw extruder with optimal process parameters. The extruder is equipped with a single-feed screw with a different pitch cutting the coil and a die with a cylindrical molding channel with a diameter of 0.019 m. The optimal extrusion mode of the fish-vegetable mixture was experimentally determined and corresponded to a pressure in the predie zone of 3.5-5 MPa, to a temperature in the predie zone of 408-413 K, to a screw rotation speed of 600 rpm.

The obtained snack samples were assessed as for the following quality indicators: physicochemical, organoleptic, microbiological contamination and product safety indicators and nutritional value. The assessment was carried out according to standardized methods in accredited food testing laboratories.

3. Results

The calculation results are summarized in the tables on which the graphs in Figure 1 are constructed. The results of a series of experiments with the assessment of physical and organoleptic quality indicators of the obtained extruded snack with rational parameters of the hot extrusion process in a single-screw extruder are shown in Table 1.

During the study, the dependences of the expansion ratio (S) on the starch content (C_s) and on the humidity (H) of the recipe mixture under the same extrusion mode were empirically revealed. The results of the experiment are shown in Figure 2a.

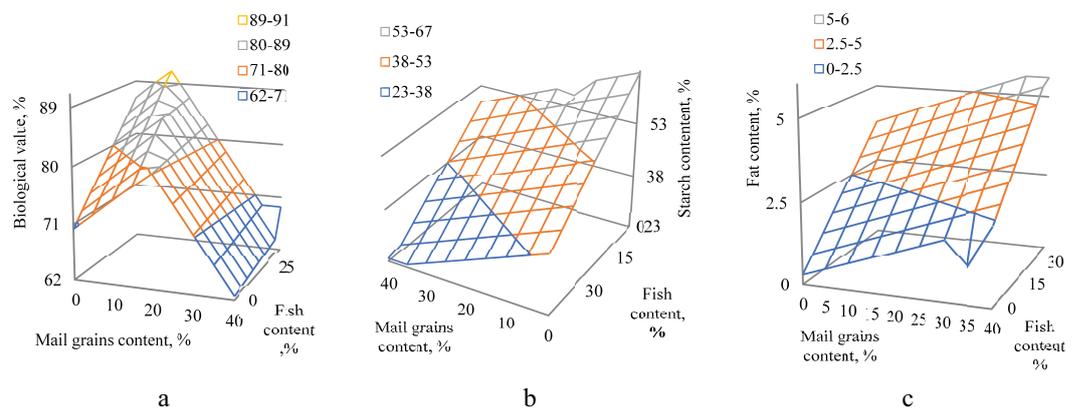


Figure 1: Nomogram for determination by biological value (a), fat content (b), starch content (c).

TABLE 1: Results of the experiment in order to determine the content of fish powder (C_f) and of malt grains (C_m) in the recipe mixture.

C_f , % to the mixture mass	C_m , % to the mixture mass	C_s , %	BV, %	S	ρ , kg/m ³	Flavor and smell
12	17	51	83	1,98	331	Not typical of potato extrudate, fishy smell and flavor
10	17	52	83	2,22	336	Not typical of potato extrudate with pronounced fish and malt flavor and the smell of fish and malt
8	17	53	82	2,59	340	Not typical of potato extrudate with fish and malt flavor and smell of fish and malt
6	17	55	81	3,26	348	Not typical of an extrudate from potato with a malt flavor and the smell of malt, the flavor and the smell of fish are weakly expressed
8	15	54	81	3,05	345	Typical of potato extrudate with pronounced fish and malt flavor and smell
8	13	55	80	3,28	351	Typical of extrudate of potato flavors with fish flavor and the smell of fried potato and fish

In Tables 2-3 and in Figure 3 show the results of laboratory tests and organoleptic quality assessment of samples of the selected composition obtained with rational parameters of the extrusion process.

As for organoleptic indicators, the product was obtained in the form of straight or slightly curved short sticks of rounded cross section, with a rough surface and developed porosity. The color of the product is yellowish brown. The taste is characteristic of an extrudate from potato with a fish flavor; the smell is of fried potatoes and fish without musty, moldy and other extraneous odors.

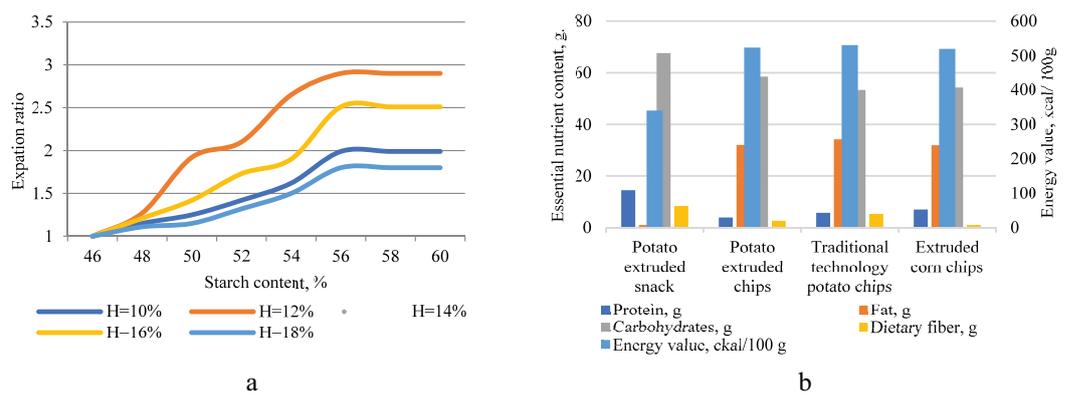


Figure 2: Dependence of the expansion ratio of the extrudate on the starch content in the recipe mixture at different humidity (a), comparison of the nutritional value of extruded potato snacks and common chips (b).

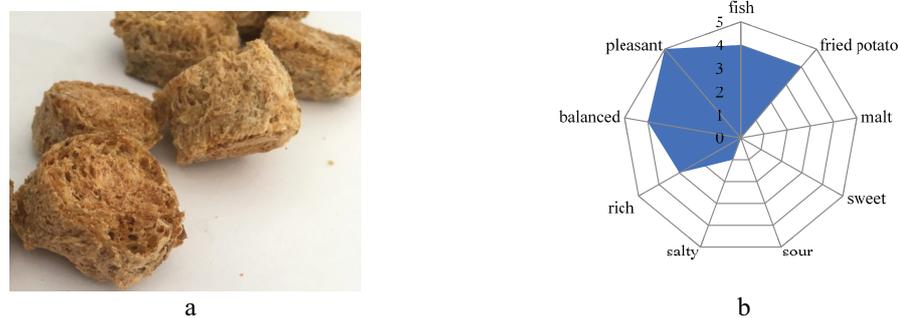


Figure 3: Organoleptic properties of extruded potato snacks: appearance (a), taste profilogram (b).

Since thermal and shear energies are applied to the raw materials during the extrusion process, causing structural and chemical changes, changes in the biological value of the product, the nutritional value of the fish-vegetable mixture will be different from the nutritional value of the extruded potato snack. In order to assess the nutritional value of the snack in Table 2 show the chemical composition. Table 3 shows the microbiological and safety indicators of the potato snack.

TABLE 2: Physicochemical characteristics and chemical composition of the potato snack.

Physicochemical characteristics	
Swelling, g / g	3.10
Water retention capacity, g / g	58.50
Bulk density, kg / m ³	340
Chemical composition	
Mass fraction of water, g / 100 g of product	4.00
Mass fraction of protein, g / 100 g of product	14.50
Mass fraction of fat, g / 100 g of product	1.00
Mass fraction of carbohydrates, g / 100 g of product	67.60
Bulk dietary fiber, g / 100 g of product	8.40
The content of thiamine (B1), mg / 100 g	0.17
The content of riboflavin (B2), mg / 100 g	1.52
Nutritional value	
Energy value, kcal	340
Biological value, %	83

TABLE 3: Microbiological and safety indicators for potato snacks.

Microbiological indicators	
E. coli bacteria	not detected
Yeast, CFU / g	less than 1x10 ¹
The number of mesophilic aerobic and facultatively anaerobic microorganisms, CFU / g	2.9x10 ³
Pathogenic microorganisms, including Salmonella	not detected
Mold, CFU / g	3x10 ¹
Bacillus cereus, CFU / g	6x10 ¹
Safety indicators	
Lead, mg / kg	less than 0.05
Arsenic, mg / kg	less than 0.1
Cadmium, mg / kg	less than 0.1
Mercury, mg / kg	less than 0.005
The specific activity of strontium-90, Bq / kg	less than 15
The specific activity of cesium-137, Bq / kg	less than 5

4. Discussion

The starch content in the calculated formulations is shown in Figure 1c as follows: the restriction is taken into account in the samples above the red region. As can be seen in Figure 1b, the fat limit is met. In Figure 1a it follows that the maximum biological value

for a limited area equal to 83% corresponds to the ratio of the recipe ingredients «fish powder -- malt grains -- dried potato» as follows: 13% -- 17% -- 70%.

A series of experiments showed that a sample of this percentage is characterized by a low expansion ratio of 1.98 and a dense low-porous structure. Poor expansion ratio is a consequence of the insufficiently high starch content in the mixture. From the analysis of Table 1 it follows that reducing the proportion of fish powder to 8% helps to achieve a sufficiently high expansion ratio of 2.59, while the product has a fairly high biological value. A decrease in the proportion of fish powder to 10% did not lead to the desired result due to the unstable occurrence of the extrusion process because of the transition «blown-fiber» structure. The transition is due to the inversion of the phases of the protein and starch in the biopolymer melt. With a fish powder content of 6%, the expansion ratio increases significantly, but the biological value and organoleptic properties of the snack are reduced. An analysis of the organoleptic properties of the obtained samples shows that all samples had a malt taste uncharacteristic for this type of product. A decrease in the content of malt grains to 13% leads to a loss of the uncharacteristic flavor of the malt.

According to the calculation results and to a series of experiments, it was found that the sample with the ratio of ingredients «fish powder -- malt pellet -- dried potato» of 8% -- 13% -- 79% is optimal.

As can be seen in Figure 2a, the highest expansion ratio belongs to a sample with a moisture content of 14% and starch content above 55%, taken as optimal. An analysis of the curves shows that increasing the starch content to 55% increases the expansion ratio for all samples. Since, with an increase in starch content, the proportion of exploding starch grains will increase. An increase in the proportion of starch over 55% slightly increases the expansion ratio, while the nutritional value of the resulting snacks decreases. The nonlinear nature of the expansion ratio curve in the growth region is due to the presence of a transitional mode with a starch content of 50-53%. For humidity curves of 10% and of 18%, undesirable effects are associated with insufficient (10%) or excessive (18%) moisture content in the recipe mixture.

An analysis of the organoleptic characteristics showed that the snack has satisfactory consumer data specific to this category of products in terms of color, taste and aroma.

The analysis of physicochemical, microbiological and safety indicators of the obtained snack in Table 2 and in Table 3 showed that they meet the criteria and requirements of sanitary rules and norms for food concentrates.

A comparison of the nutritional values of the developed snack and of extruded snacks that are widely available on the market is shown in Figure 2b. It can be seen that the

developed product contains 73% more protein and 69% more dietary fiber than potato extruded chips. At the same time, the developed snack contains 3.12 times less fat and has a lower energy value (by 35%). The low fat content is due to their low content in the initial mixture and the limitations of the extrusion process. When eating 100 grams of snacks, 19% of the adult's daily protein requirement and 28% of dietary fiber are satisfied, while the daily diet is not overloaded with calories and does not contain excessive fat. Thus, this product is a healthier alternative to the snacks on the market.

5. Conclusion

The demand for snacks corresponding to the concept of a balanced diet for the most part remains unsatisfied. This study allows partially solving this issue, improving the quality of food for the urban population with a modern rhythm of life.

The study scientifically substantiated and experimentally confirmed the content of the components of the fish-vegetable mixture for the production of enriched expanded extruded potato snacks, consisting of 79% of dried chopped potatoes, of 13% of dried beer grains and of 8% of fish powder obtained from salmon fillet meat waste. The specified composition helps to increase nutritional value and to reduce the product cost, to improve the taste and sanitary conditions of the use of fish. The use of offals of fish processing and brewing industries in combination with low-waste extrusion technology leads to the maximum saving of production resources and of the environment.

The developed potato snack has a high nutritional, biological and low energy value, netter consumer indicators in comparison with analogues. A distinctive feature of the snack is the presence in the composition of increased protein content of 14.5% and of dietary fiber 8.4%, a reduced fat content of 1%. The contingent of potential buyers of this snack can be attributed to wide categories of people, including overweight people, athletes and adherents of an active lifestyle, schoolchildren and students who constantly experience hunger due to active growth and intense mental work. Taking into account the demand for snacks of a balanced composition, availability and cost of raw materials, taking into account the organoleptic assessment and high nutritional value of the developed extruded potato snack, it is recommended to introduce this technology.

References

- [1] Alam, M. S., Kaur, J., Khaira, H., et al. (2016). Extrusion and extruded products: changes in quality attributes as affected by extrusion process parameters: a review. *Critical Reviews in Food Science and Nutrition*, vol. 56, pp. 445–473.
- [2] Stojceska, V., Ainsworth, P., Plunkett, A., et al. (2010). The advantage of using extrusion processing for increasing dietary fibre level in gluten-free products. *Food Chemistry*, vol. 121, pp. 156–164.
- [3] Onwulata, C. I., Smith, P. W., Konstance, R. P. et al. (2001). Incorporation of whey products in extruded corn, potato or rice snacks. *Food Research International*, vol. 34, pp. 679–687.
- [4] Nath, A., Chattopadhyay, P. K. (2008). Effect of process parameters and soy flour concentration on quality attributes and microstructural changes in ready-to-eat potato-soy snack using high-temperature short time air puffing. *LWT - Food Science and Technology*, vol. 41, pp. 707–715.
- [5] Nayak, B., Liu, R. H., Berrios, J. D. J., et al. (2011). Bioactivity of antioxidants in extruded products prepared from purple potato and dry pea flours. *Journal of Agricultural and Food Chemistry*, vol. 59, pp. 8233–8243.
- [6] Ostrikov, A. N., Sokolov, I. Y., Vasilenko, V. N. (2009). *Co-extrusion Products: New Approaches and Prospects*, Moscow, M: Delhi-Print.
- [7] Sakaguchi, M. (2004). *More Efficient Utilization of Fish and Fisheries Products*, Elsevier Science.
- [8] Raatz, S., Bibus, D. (2016). *Fish and Fish Oil in Health and Disease Prevention*, Academic Press.
- [9] Wijesekara, I., Kim, S.K. (2010). Angiotensin-I-converting enzyme (ACE) inhibitors from marine resources: prospects in the pharmaceutical industry. *Marine Drugs*, vol. 8, pp. 1080-1093.
- [10] Netto, J. D. P. C. (2014). Physicochemical and sensory characteristics of snack made with minced Nile tilapia. *Food Science Technology*, vol 34, pp. 591 -- 596.
- [11] Kumar, R., Xavier, K.A.M., Lekshmi, M., et al. (2017). Development of functional extruded snacks by utilizing Paste shrimp (*Acetes* spp.): Process optimization and quality evaluation. *Journal of the Science of Food and Agriculture*, vol. 98, DOI: 10.1002/jsfa.8731.
- [12] Shaviklo, G. R., Thorkelsson, G., Rafipour, F. et al. (2011). Quality and storage stability of extruded puffed corn-fish snacks during 6month storage at ambient temperature. *Journal of the Science of Food and Agriculture*, vol. 91, pp. 886–893.

- [13] Stojceska, V., Paul, A., Andrew, P. et al. (2008). The recycling of brewer's processing by-product into ready-to-eat snacks using extrusion technology. *Journal of Cereal Science*, vol. 47, pp. 469–479.
- [14] Ai, Y., Cichy, K. A., Harte, J. B., et al. (2016). Effects of extrusion cooking on the chemical composition and functional properties of dry common bean powders. *Food Chemistry*, vol. 15, pp. 538-545.
- [15] Roe, M., Pinchen, H., Church, S. et al. (2015). McCance and Widdowson's The Composition of Foods Seventh Summary Edition and updated Composition of Foods Integrated Dataset. *Nutrition Bulletin*. 40. 10.1111/nbu.12124. Wiley Online Library.