Planning an experimental technology of expanded snacks

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Abstract. In this paper we analyse the state-of-the art production of extruded snack foods. We described the properties of the raw materials used for manufacture of snacks and suggested methods to study the chemical composition of raw materials and finished products. We retrofitted a single screw extruder by feeding carbon dioxide at a pressure of up to 4.0 MPa to the final part of the apparatus which allowed us to reduce the treatment time and to improve the quality of products. The obtained kinetic dependence values helped develop the optimal operating conditions for the modified extruder. The established kinetic dependence allowed us to find out the relationship between temperature and pressure in the pre-matrix zone of the single screw extruder and determine the expansion ratio of extruded product depending on the outlet area of the extruder die within 2.0-2.8·10^{-4} m^2. The obtained optimal parameters of the technology of multicomponent blend extrusion with a blend moisture of 30%, a screw speed of 11 rps and a pressure of 4.5 MPa helped determine the required properties of expanded porous-textured snacks with an expansion ratio up to 300%. A method for production of a new kind of extruded nut-added snacks was developed which formula includes inexpensive by-products of high nutrition value.

1. Introduction
New healthier foods can be produced at fast food facilities by using extrusion technology [7,9,10]. The main objective of this study was to improve the extrusion of the fast-food-type snack products. To achieve this goal we reviewed the literature for scientific and technical information and evaluated the raw material composition.

The selection and preparation of raw material are an essential part of planning any experimental technology for production of snack foods. There are methods where new extruded foods are developed which include by-products of slaughter and processing of farm animals, collagen-containing raw materials in particular [1,3].

The main stage of preparation of raw material for extrusion is determining the rational parameters of its dehydration [2,5]. In order to provide mathematical support of extrusion we suggest designing an experiment [4,6].

Gas and liquid technology in snack foods manufacture is one of highly innovative solutions [8]. The research of the effect of extrusion processing on product parameters, such as the contents of valuable nutritional components, also proves very interesting [11]. By optimising extraction and extrusion we can ensure extrudates with predetermined properties, e.g. with a guaranteed dietary fibre content [12-14].
2. Materials and methods

The object of the study was the collagen-containing raw material *Universal collagen-containing food additive* conforming to the technical requirements TU 10.89.19-491-02067862-2020 (Russian standard). It was obtained from by-products of poultry processing which were preliminary treated by enzymatic hydrolysis. We also added sub-cheese whey and chitosan (as a texturing agent) to the formulation of snack products.

Plant raw materials used in the initial snacks formulations were starch, nuts, pulse and cereal flour, and CO₂-extracts of spices. Light water with low deuterium content was prepared according to the technical regulations TU20.13.61-492-02067862-2020 – *Light water with low deuterium content* (Russian standard), taking into account the difference in the temperatures of freezing of protium water (0°C) and deuterium water (+3.8°C).

We used a modified single screw extruder with carbon dioxide fed to the bottom. The qualitative properties of the extrudates were analysed for swelling, water retention, bulk weight, water and moisture content.

We employed the technology developed by the specialists of the Animal Source Food Technology Department of the Kuban State University: crushed and petal-shaped nut and cereal raw material was then pre-treated with liquid carbon dioxide. The characteristics of the extracts obtained are given in TU 10.89.15-478-02067862-2019 *CO₂-extracts from cereal and nut raw material* developed at Kuban State Technological University.

Light water with low deuterium content was obtained by freezing-out since its temperature of freezing is different from that of ordinary water.

3. Results

The developed technological solutions were experimentally approved in factory.

Nut-based extrudates are ready-to-eat products which don’t need further processing. The technology of their production includes the preparation of raw material, its blending, conditioning and resting, and the following shaping of nut sticks.

The basic equipment used for manufacture of nut sticks is the modified extruder with pumped carbon dioxide at a pressure of up to 4.0 MPa. Before use, the extruder was heated for an hour. Then the batch hopper was charged with 3–4 kg of conditioned to the 23–24% moisture content and the nut batch was sent to processing with the chute slide-valve kept open. The machine was operating at a temperature of 170–180°C. The charged mix was gradually heated in the extruder zones from 60°C to 110°C and then cooled by CO₂ feeding to 30°C.

A cross-section of the modified extruder with pumped carbon dioxide is shown in Figure 1.

![Figure 1. A cross-section of the modified extruder with pumped carbon dioxide](image)

1 – extruder die, 2 – cooling channels, 3 – heating channels, 4 – batch hoppers, 5 – moisture outlets, 6 – supply zone 1, 7 – shaping zone 2, 8 – discharge zone 3.
Equipment for nut sticks manufacture is pictured in Fig. 2.

![Figure 2. Equipment for nut sticks manufacture. 1 – extruder with pumped carbon dioxide, 2 – bin, 3 – conveyor, 4 – panner.](image)

For further coating or flavouring nut sticks are fed to a special storage bin, then they are conveyed to a panner where they added CO$_2$ extracts in vegetable oil or other additives depending on the assortment. The finished sticks are packaged.

The extrusion method with pumped CO$_2$ for processing raw material allows us to produce new snack foods which are porous but with smooth surface. Powdered stuff is mixed with carbon dioxide and injected into the chamber with lower pressure. Due to the sharp pressure drop the powder becomes highly dispersed and condenses on the walls of the vessel as a thin film.

Dry aerated products are volumetric smooth sticks which are porous inside and have the designed flavor. Their multi-layer surface consists of starch, chitosan and a nanolayer of CO$_2$-extracts.

4. Discussion

The formulation of the extruded snack foods is composed of collagen-containing raw materials, nuts of three kinds, legumes, corn starch and CO$_2$-extracts. The amaranth cake remaining after CO$_2$ extraction of oil from amaranth seed is also used. It is low-cost and contains native protein, carbohydrates, vitamins and trace elements. Dried sub-cheese whey containing valuable nutrition substances is used to enrich dry breakfast foods.

The formulations of the extruded snack foods are given in Table 1.

| Raw material               | Formulation 1 | Formulation 2 | Formulation 3 | Formulation 4 |
|----------------------------|---------------|---------------|---------------|---------------|
| Collagen-containing raw material | 17.0 | 18.0 | 20.0 | 14.0 |
| Corn starch                | 2            | 3            | 2            | 2            |
| Almond after CO$_2$-treatment | –    | 6             | –             | 3             |
| Buckwheat flour            | 40.0         | 50.0         | 60.0         | 45            |
| Lentil powder              | 8            | 7            | 6            | 5            |
| Walnuts after CO$_2$-treatment | 7   | –             | –             | 8             |
| Pistachios after CO$_2$-treatment | – | –             | 6             | –             |
| CO$_2$-caraway extract     | 0.001        | 0.003        | 0.005        | 0.004         |
| Dye sub-cheese whey        | 6.5          | 8.0          | 5.0          | 4.0           |
| CO$_2$-amaranth cake       | 3.5          | 4.9          | 5.5          | 4.0           |
| Chitosan                   | 0.4          | 0.3          | 0.5          | 0.3           |
| Light water                | up to 100 %  | up to 100 %  | up to 100 %  | up to 100 %  |

The organoleptic evaluation of nut sticks was made according to the five point scale. The products were evaluated 4.5–4.7 by the panelists.

The rheological parameters of the extruded snack foods are shown in Table 2.
Table 2. Rheological parameters of the extruded snack foods

| Parameters                          | Values           |
|-------------------------------------|------------------|
|                                    | Formulation 1 | Formulation 2 | Formulation 3 | Formulation 4 |
| Swelling properties, mg/g           | 7.2            | 7.0            | 6.5            | 6.0            |
| Water retention property, %         | 142            | 135            | 131            | 120            |
| Bulk weight, g/cm³                  | 85             | 80             | 87             | 84             |
| Fat content in dry substance, %     | 30             | 35             | 25             | 20             |
| Moisture content in the product, %  | 6              | 7              | 8              | 9              |

The process of subcritical CO$_2$-extraction allows us to remove easily oxidized components (reducing the shelf-life) from the grinded nuts. In addition, we obtain a valuable product for cosmetic media in the form of CO$_2$-extracts the realization of which could partially cover the costs of snack foods production.

The biochemical evaluation of the snack foods quality showed that the finished products contain more essential amino acids as compared to the raw material. They are rich in such deficient elements as lysine, threonine, valine and leucine. Isoleucine is present in minor quantities.

5. Conclusion
The obtained theoretical and experimental data allowed us to develop a method for production of new extruded nut snack foods whose formulation included low-cost by-products of high nutrition value.

The present work is relevant due to the following:

– the development and industrial approval of an innovative technology of expanded nut snacks manufacture for fast (convenience) food;

– the retrofitting of a single-screw extruder by feeding carbon dioxide at a pressure of up to 4.0 MPa to the bottom which reduced the processing time and improve the quality of products;

– the revealed kinetic dependence values helped develop the optimal operating conditions for the modified extruder which allowed establishing the relation between temperature and pressure in the pre-matrix zone and determine the expansion ratio of the extrudates in dependence on the exit diameter of the die within 2.0-2.8·10$^{-4}$ m$^2$;

– the determining of the optimal parameters of the technology of multicomponent blend extrusion (with a blend moisture of 30%, a screw speed of 11 rps and a pressure of 4.5 MPa) helped determine the required properties of expanded porous-textured snacks with an expansion ratio up to 300%.

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