MEAT AND PLANT PRODUCTS DESIGNING BASED ON THE MULTILEVEL MODELING METHOD

Aleksander A. Borisenko¹, Andrey A. Bratsikhin¹*, Ludmila A. Saricheva¹, Aleksey A. Borisenko¹, Gennady V. Slyusarev², Evgeniy A. Chebotarev¹

¹Life Sciences Institute, North Caucasus Federal University, Pushkina street 1, Stavropol, 355009, Russian Federation
²Institute of Information Technologies and Telecommunications, North Caucasus Federal University, Pushkina street 1, Stavropol, 355009, Russian Federation

*email: aab.science@gmail.com

Abstract
Advanced technology of meat products with balanced nutrient content design based on the mixing of the animal and plant origin raw materials that provide the modern trend in supporting the people by complete ration and satisfy their physiological needs. Solution of the problems dealing with food component’s interaction modeling and optimal ratio between ingredients finding as well as properties of the final products prediction is a critical things for industry and science.

Developed methodology of multilevel modeling is used for technology of chicken nuggets development and for designing of nugget’s formulation by authored computer modeling program and activated water using. Computer designed nugget’s formulation has high nutrient value (calculated value was 91.88%) and low calorific capacity (128.6 kcal for 100 gram of product) and contained vitamins of B, C, A, E, D-group and mineral substances. It was proved that catholyte can improve emulsifying capacity of the soya protein isolate till 150 g on the 1 g of the protein that can be used for non-chemical sensory and technological properties of minced meat products development. Results of experimental work show that developed nuggets have high biological value and corresponded to the modern conception of healthy food.

Key words: formulation design; balanced nutrient content; nuggets; soy isolate; emulsifying stability; electro-chemical activated water

1. Introduction
Modern trends and perspectives for high quality foodstuffs development are based on the methods of meat and plant raw materials combination, which is oriented on the nutrients content balancing and high biological and nutritional values of the foodstuffs and enrich them by essential biocorrectional ingredients and bioactive elements [1 - 5].

It is known that raw meat has not been balanced of the essential kinds of nutrients as amino acids and fat acids content, vitamins and mineral elements, and it is not possible to design the foodstuffs from one meat ingredient which can satisfy all of physiological human needs. Therefore, using vegetables and beans, root plants and nuts, mushrooms and products of their processing as additional ingredients in meat foodstuffs formulation has an actual and perspective ways of development [2, 3].

Results from the analysis of meat foodstuffs market show that chicken nuggets are very popular among the consumers in many countries. Base raw material for their production is a chicken fillet. Nuggets have a tender structure and light color, but also they have a high self-cost, hence manufacturers are looking for the new technological ways of its reduction, which includes the meat alternatives and flavoring additives that can be used for meat replacement.

The goal of research was development of new kind minced meat-and-plant semi-foodstuffs (nuggets),
which would have a balanced nutrient content and low calorific value, high sensory properties and reduced self-cost, and in the same time will be enriched by natural functional ingredients.

2. Materials and Methods

2.1 Methods of theoretical research and computer modeling

Molecular modeling and quantum chemical calculations were provided by special computer programs complex VMD (Visual Molecular Dynamics) and NAMD (Nanoscale Molecular Dynamics) [6, 14]. Subunit of A3B4 [7] 11S globulin molecule was placed in the center of virtual water box with different types of dispersion medium. The geometrical optimization was made and then the modeling of system’s component interaction was made by method of molecular dynamics at temperature 20 °C.

Modeling of chicken nuggets formulation and optimization of their nutrient content as well as assessment of the nutritional and biological values were realized on the developed program “Etalon” [8]. Program used the authors original algorithms, searches and offers the optimal formulation of multi-component foodstuffs, which will be balanced for nutrients contents and have more desirable physicochemical properties and low self-cost. Parameters which were established and recommended by both of Food and Agricultural Organization and World Health Organization were used as etalon for matching to the developed formulation.

2.2 Methods of raw material and nuggets’ properties research

Emulsifying capacity was determined by method Inklaar P. and Fourtuin J. Using in emulsions which were made in homogenizer based on the 1% protein solution and oil adding at the constant rate of mixing [9, 10].

Water-binding capacity was determined by drying of the samples till the constant mass is fixed at (103 ± 2) °C [18, 19].

Protein content was found by titrimetric method of Kjeldahl [18, 20] and fat concentration was calculated after studied samples drying by Soxhlet [18, 21].

Quantity of mesophilic aerobic and facultative anaerobic microorganisms was calculated by method of sample’s inoculation on agar medium [22]. Quantity of coliform bacteria and *Staphylococcus aureus* were determined by MPN technique for low numbers of bacteria [23, 24] and presence of pathogen microorganisms was found by horizontal method for the detection of *Salmonella* spp. [25].

Method of enzyme multiplied immunoassay was used for antibiotics quantitation [26, 27, and 28]. Mass ratio of lead and cadmium were calculated by electrothermal atomic absorption spectrometry method [29], and mercury - by colorimetric method, and arsenic - by atomic absorption analysis [30, 31].

3. Results and Discussion

Development of chicken nuggets formulation was based on the new methodology of multilevel modeling, which includes the next stages:

- Modeling of the molecular (inter and intra molecular), cluster and intercluster interaction of foodstuffs ingredients chemical content (intermolecular level);
- Optimal nutrient and ingredients content calculations of the food (nutritional level);
- Assessment and prediction of the functional and technological properties of the food mixtures and model food systems (middle level);
- Consumer properties of the foods modeling like sensory characteristics (odour, flavour, texture and mouthfeel), and appearance with consumer attitudes and health biases (macro-level).

There are special functional properties that should be regulated for meat-and-plant products manufacturing: solubility, viscosity, water-binding and emulsifying and gel-forming capacity. The general directions for regulation of the listed properties are in optimal physicochemical and thermodynamical parameters of treatment selecting, and biotechnological methods and physical processing using [9, 10, 11].

One of the principle questions in foods technology is a non-chemical method of the raw materials treating and one of the perspective methods in that direction is use of electrochemical activated water. The most important factor of anolyte and catholyte that are the fractions of the electrochemical activated water is chemically regulated pH level as well as energy potential characterized by the redox-potential and dielectric permittivity and some other parameters [12, 13].

Results of the study from the catholyte and anolyte influence on the functional properties of the soya 11S-globulin by the molecular modeling and quantum chemical analysis were used for prediction of the protein behavior under the different types of the dispersion water medium [15]. It was proposed that hydration properties of the studied protein could be improved if the catholyte would be used instead of the water because of the surface of the protein’s active centers increasing that would be attacked by the electrophilic and nucleophilic agents.

Experimental research was carried out for theoretical proposal validation on the next step of work that were
devoted to study of the soya isolate emulsifying capacity under the different dispersion medium. It was established (Figure 1) that catholyte provided more stable emulsion till 70% of oil in the system in spite of the drinking water using. Optimal oil content in the studied system was 60% and emulsifying capacity of the soya protein isolate was at 150 g on the 1 g of the protein.

Therefore the results of natural experiments shown that soya proteins hydrated by the catholyte were more effective in role of emulsifying agents and water-binding components than in cases when proteins hydrated by drinking water. Listed behavior of protein is corresponded with computer modeling results and quantum and chemical calculations obtained for other types of proteins [16, 17].

Computer modeling of the nuggets formulation on the nutrient level was done on the next step. There basic raw materials were: chicken meat (breast), mechanical deboned poultry meat, carrot, white cabbage, paprika, dried mushroom, chicken fat, soya isolate, egg product and additional materials like bread crumb, salt, spices and catholyte.

Meat and plant origin raw materials combination by programme “Etalon” using let design the final products with high nutrient value (calculated value was 91.88%) and low calorific capacity (128.6 kcal for 100 gram of product), which had the high level of balance in essential amino acids in relation to FAO/WHO (Table 1) and contained vitamins of: B, C, A, E, D-group, and mineral substances like: calcium, phosphorus, potassium, magnesium, iron, manganese, zinc, selenium.

New technology of balanced chicken nuggets based on the molecular and nutrient modeling results and catholyte using instead of drinking water was developed.

Meat must be minced on the grinder with plate holes diameter of 9 mm (50% of meat fillet mass) and 2 - 3 mm for the rest part of meat materials. Carrot, white cabbage and paprika must be cleaned and peeled, and grinded in grinder plate with holes of 2 - 3 mm. Soya isolate must be hydrated by the catholyte (pH = 10.5 and redox potential is around -300 mV) in ratio 1 : 9. Prepared ingredients should be mixed in 5 - 6 min. and formed in nuggets covered by dried bread crumb. Formed nuggets are produced in freeze condition without heat treating or as totally ready for eating (after reheating). Freezing is provided at -18 °C or -35 °C till temperature in the center of product set up to -10 °C.

Heat treating of the dietary nuggets should be made by warm air at t = 180 - 220 °C and traditional treating should be made in open frying surface with small amount of oil.

![Figure 1. Emulsifying capacity of the soya protein isolate](image)

Table 1. Amino acid balance of the new chicken nuggets

<table>
<thead>
<tr>
<th>Amino acids</th>
<th>Content in the chicken nuggets</th>
<th>Recommended by FAO/WHO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leucine</td>
<td>7.42</td>
<td>7.0</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>3.82</td>
<td>4.0</td>
</tr>
<tr>
<td>Lysine</td>
<td>6.29</td>
<td>5.5</td>
</tr>
<tr>
<td>Methionine + Cystine</td>
<td>3.40</td>
<td>3.5</td>
</tr>
<tr>
<td>Phenylalanine + Tyrosine</td>
<td>7.13</td>
<td>6.0</td>
</tr>
<tr>
<td>Threonine</td>
<td>4.13</td>
<td>4.0</td>
</tr>
<tr>
<td>Tryptophane</td>
<td>1.39</td>
<td>1.0</td>
</tr>
<tr>
<td>Valine</td>
<td>4.54</td>
<td>5.0</td>
</tr>
</tbody>
</table>
Results of industrial approbation were shown that sensory and physicochemical properties as well as parameters of safety correlated to normative requirements and principles of healthy food (Table 2).

Quantity of fat in the developed nuggets was reduced by at least 30% in comparison with traditional formulation that allowed producing calorie reduced products. Low level of microbial contamination was a result of activated water using instead of drinking water: catholyte was used as an ingredient of formulation and anolyte was used for washing of raw materials before processing. Sensory properties of the nuggets had the highest values that were corresponded with “good” and “excellent” degree.

4. Conclusions
- Results of foods computer modeling and experimental research shown that using catholyte instead of drinking water for soya protein hydration provided more stable protein-fat emulsion making.
- Balanced nutrient content chicken nuggets were designed by author programme “Etalon” that had high biological value and low calorific capacity.
- Methodology of the multilevel modeling placed on the base of listed research let to design the new type of combined meat and plant origin products for healthy food with high consuming properties.
- Usage of natural ingredients, as well as balanced nutrient content of the developed nuggets and high level of their safety, is recommended for this developed formulation and technology for industrial adaptation and can be extended to the range of the healthy foods on the market.

5. References