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Original scientific paper

Development of functional meat cutlets with improved nutritional value and antioxidant properties to correct the diet of patients with cardiovascular disease

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A R T I C L E I N F O

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A B S T R A C T

Taking into account the modern recommendations for patients to reduce cardiac risk, a recipe for functional meat cutlets was developed. The product features the substitution of saturated fatty acids with polyunsaturated ones, the reduction of the level of table salt and adding biologically active substances with pronounced antioxidant properties. The introduction of rapeseed oil instead of beef fat made it possible to significantly reduce the content of saturated fatty acids and increase the ratio of unsaturated fatty acids, thus providing a given ratio of PUFA:SFA in the range of 2.3–1.6. The test sample did not contain *trans*-fats. The results of studies of the antioxidant capacity of cutlet samples showed that the total background antioxidant capacity of the test sample was 9 times higher than in the control sample. The introduction of the antioxidant complex contributed to the preservation of the high antioxidant capacity of this product during its storage. It is possible to recommend inclusion of this product into the diet designed for cardiovascular disease prevention as a source of complete protein, vitamins and minerals.

1. Introduction

Cardiovascular diseases (CVD) are currently the main cause of deaths worldwide (*Smetneva et al.*, 2020). The contribution of dietary correction to progression of CVD ranges from 10% to 40%, which is quite comparable to the effect of drug therapy (*Petrikov et al.*, 2023). Diets enriched with ω3 fatty acids (≥ 0.85 g/day), containing an increased level of polyunsaturated fatty acids (PUFAs), and a reduced level of fat in the daily diet (less than 30%), have a significant capacity to reduce the risk of general mortality and mortality caused by CVD (*Petrikov et al.*, 2023).

Meat is the main source of complete animal protein (*Dydykin et al.*, 2022). Recently, however, several meta-analyses have linked high rates of red meat and processed meat consumption to various health conditions, including CVD (*Leroy et al.*, 2020, *Johnston et al.*, 2019; *Vernooij et al.*, 2019; *Zeraatkar et al.*, 2019). The lipid fraction of some kinds of meat is characterized by a relatively high content of saturated fatty acids (SFAs) and cholesterol, dietary intake of which is traditionally associated with an increased risk of CVD.

It has been shown that the characteristics of the meat, along with the overall chemical composition of the diet, are to be rather considered as important

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factors. For example, the addition of 500 g/week of unprocessed lean (<10 g total fat, <5 g saturated fat, and <95 mg cholesterol per 100 g product) red meat to a cardioprotective diet did not result in increased CVD risk or adverse effects on blood lipid levels (*Vernooij et al.*, 2019).

In addition to the role of SFA and low-density cholesterol in atherogenesis, the role of oxidized lipoproteins in vascular disorder aetiology is also important (*Ahotupa et al.*, 2017, *Del gado et al.*, 2021; *Dehghan et al.*, 2017, *Mente et al.*, 2017). Some types of lipids are easily oxidized, forming a complex mixture of oxidation products that are actively involved in inflammatory reactions in atherosclerosis (*Testa et al.*, 2018). Oxidized lipids can be generated internally as well as supplied in the diet (*Otaegui-Arrazola et al.*, 2010). Lipid oxidation also occurs during the passage of meat through the various parts of the gastrointestinal tract, as the oxidation is facilitated by haeme iron, high levels of PUFAs, and the absence of suitable antioxidants (*Van Hecke et al.*, 2017). Vitamins A, C, E and D serve as components with antioxidant properties; the same is true for polyphenols, whose anti-radical properties are associated with the availability of several hydroxyl groups (*Bobrysheva et al.*, 2023).

Provided it is managed to level the existing negative factors, the introduction of functional meat products into common practice will help to adjust preventive diets. Based on relevance presented above, the aim of the research was to develop the nutrient composition of functional meat cutlets to correct the diet of patients with CVD, and to investigate the nutritional value and antioxidant properties of the functional cutlets.

2. Materials and methods

The object of the study were: green tea extract (polyphenol content 95%), (LLC Kazan Plant of Extracts); composition of vitamins and minerals (B6, B12, C, D3, E, calcium, magnesium); ready-to-eat meat cutlets – test sample and control sample.

To prepare the control samples of cutlets, minced meat (beef and chicken, in a 1:3 ratio) was used. Also, oatmeal flour, beef fat, chicken eggs, milk protein, salt and water were added. The content of table salt in minced meat was 2.0 g/100 g. The test samples were prepared according to a similar recipe, but with the replacement of beef fat with rapeseed oil and enriched with a vitamin-mineral complex and green tea extract. The content of table salt in minced meat was 0.9 g/100 g.

The prepared semi-finished cutlets were brought to culinary readiness (up to 85°C inside the product) in a Unox XVC 304 Chef Top LI1615AO steam convection oven (UNOX S.r.J, Padova, Italy) on the "steaming" mode for 100% of the cooking time, at a temperature of 110°C.

The prepared cutlet samples were tested in the Testing Center of the V.M. Gorbatov's Federal Research Center for Food Systems of the Russian Academy of Sciences (Accreditation Certificate No. RA.RU21PP69) according to the following research methods: The mass fraction of protein was determined according to the method of Kjeldahl (*GOST 25011-2016,* 2017). The mass fraction of fat was determined according to the major method of Soxhlet (*GOST 23042-2015,* 2017). The mass fraction of fat-soluble vitamins D_3 and E was determined by a method based on alkaline hydrolysis of a product sample and extraction with diethyl ether (*GOST 32307-2013,* 2013). Quantitative determination of water-soluble vitamins B_{12}, B_6 and C was carried out by high performance liquid chromatography in the ultraviolet range of the spectrum with a specified wavelength (*GOST R 55482-2013,* 2013). The mass fraction of magnesium (Mg) was determined by the flame atomic absorption method (*GOST R 55484-2013,* 2013). Determination of the mass fraction of calcium (Ca) was carried out by the atomic absorption method (*GOST R 55573-2013,* 2013). The acid value of the samples was determined by the titration of free fatty acids with a potassium hydroxide solution according to method *GOST R 55480-2013* (2013). The peroxide value of the samples was determined by titration with sodium thiosulfate solution and the quantitative determination of released iodine (*GOST 34118-2017,* 2017). The composition of fatty acids was determined by gas chromatography (*GOST R 55483-2013,* 2013) on Agilent 7890A automatic gas chromatograph (Agilent Tech., USA) with a flame ionization detector. A Supelco SP 2560 100m x 0.25mm x 0.2mkm chromatography column (Supelco, USA) was used to determine fatty acids. Total antioxidant capacity (TAC) was determined according to the FRAP (Ferric Reducing/Antioxidant Power) method.

All experiments were performed in triplicate. The data obtained were expressed as the mean value of triplicates ± standard deviation. Significance was determined by two-way analysis of variance (ANOVA) with Duncan's multiple range tests using SPSS Statistics 19.0 software (IBM Corp., USA). The selected significance level for all statistical tests was equal to 5% ($p < 0.05$).

3. Results and discussion

Taking into account the current recommendations of the World Health Organization, the main marker indicators of functional meat cutlets for the prevention of CVD and their values are determined (Table 1) (*WHO*, 2017; *Starodubova et al.*, 2020; *MR 2.3.1.0253-21*; *Petrikov et al.*, 2023).

The concentrations of functional ingredients in the specialized products should be between 15% and 50% of the average daily requirement of the respective nutrient. At the same time, functional ingredients should not deteriorate the nutritional value of the product and its consumer properties (*Kodentsova et al.*, 2020). Table 2 shows the list and the required level of application of functional ingredients that provide a positive effect on cardiovascular pathology.

Along with cardioprotective effects, vitamins C, E and D have antioxidant effects on free radicals

Table 1. Guidelines for food composition to reduce cardiac risk

Nutrients	Recommended daily intake	Recommended content per 100 g of product	Guidelines for intake level to reduce cardiac risk
Protein, g	80.0	Not less than 15.0	Consume an adequate amount of protein
Fat, g	70.0	Not more than 7.0	Reducing fat content to 30% of dietary energy, substitution of animal fats with vegetable fats
SFA, g	23.0	Not more than 1.5	Less than 10% of energy
MUFA, g	25.0	1.5–2.5	10–15% of energy
PUFA, g	22.0	Not less than 1.5	7–10% of energy
Ratio of PUFA:SFA	2.3–1.6	2.3–1.6	
Cholesterol, mg	less than 300	6–30	
Trans fats	→ 0	0	Less than 1% of energy
Table salt, g	less than 5.0	Not more than 1.2	Limited sodium intake

Table 2. Composition and recommended levels of functional ingredients

Nutrients	Recommended daily intake (MR 2.3.1.0253-21)	Recommended content per 100 g of product	Known cardioprotective effects (*Smetneva*, 2020; *Yardim-Akaydin*, 2003)
Flavonoids Flavan-3-ols, mg	200	not less than 100	Prevention of the development of atherosclerosis, normalization of tissue respiration
Vitamin B_6, mg	2.0	0.3–1.0	Improves the condition of blood vessels, regulates blood pressure
Vitamin B_{12}, μg	3.0	0.45–1.5	Protects vessel walls from compaction
Vitamin C, mg	100.0	15.0–50.0	prevents the processes of lipid peroxidation
Vitamin D_3, μg	15	2.25–7.5	Affects DNA methylation processes by altering the expression of many CVD-associated genes
Vitamin E, mg	15	2.25–7.5	Protects heart muscle from free radicals damage
Magnesium, mg	400.0	60.0–200.0	Restores heart rhythm
Calcium, mg	1,000.0	150.0–500.0	Contributes to lowering blood cholesterol levels

(*Smetneva et al.*, 2020; *Yardim-Akaydin et al.*, 2003). The same effects are found in flavonoids (including isoflavones), an effective source of which is green tea.

To confirm the efficiency of the green tea extract containing 95% polyphenols and the composition of vitamins and minerals, their TAC was evaluated. In the tested samples of green tea extract and composition of vitamins and minerals TAC was 442.424±0.398 and 147.204±2.777 µmol eq quercetin/g, respectively. The analyzed green tea extract containing 95% polyphenols proved to have a high antioxidant capacity (*Yang et al.,* 2016).

The fat composition of cutlets was modified by replacing beef fat with rapeseed oil, which is a source of ω-3 PUFAs. In rapeseed oil, oleic acid (OA: C18:1 n-9) is the most abundant (its share is 59%), followed by linoleic acid (LA: C18:2 n-6) with 19% and alpha-linolenic acid (ALA: C18:3 n-3) with 9%, but it lacks LC-PUFAs such as EPA and DHA *ω*-3 fatty acids (*Willora et al.,* 2021).

Several authors have added ω-3 PUFAs to enrich meat food. *Solomando et al.* (2020) added encapsulated fish oil to model meat systems to increase ω-3 content. *Lorenzo et al.* (2016) enriched the Spanish salchichon sausage to obtain better lipid formulations. Due to this enrichment, the total amount of PUFA in modified sausages was increased by 2.3%.

The results of the chemical composition of the test and control samples of cutlets are presented in Table 3.

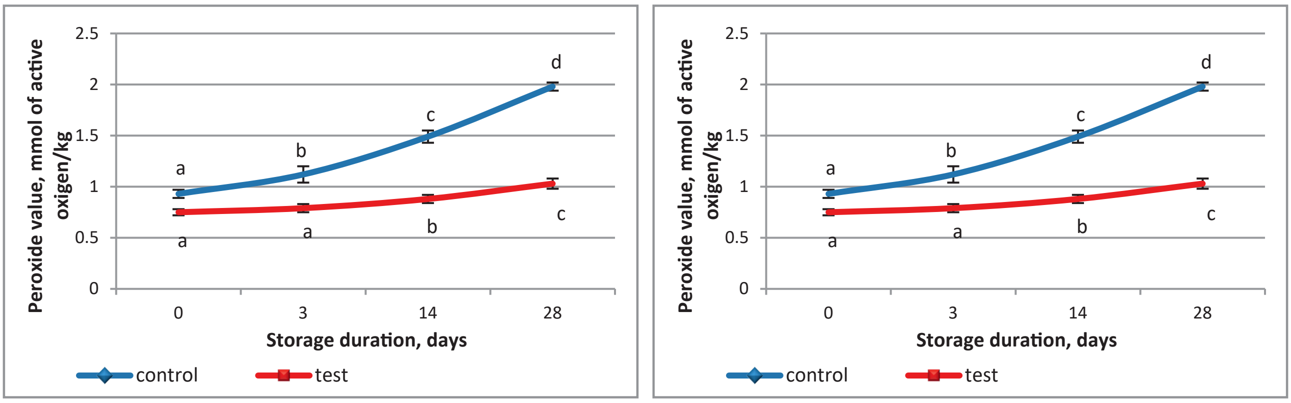
As can be seen from the above data, the use of rapeseed oil instead of beef fat significantly reduced the SFA content and increased the unsaturated fatty acid content, resulting a specific PUFA:SFA ratio

Table 3. Results of the analysis of the chemical composition of the samples

Parameter	Content per 100 g of cutlet	
	Control cutlet	Test cutlet
Protein, g	16.9±2.5	17.1±2.6
Fat, g	6.5±1.0	6.3±1.0
ΣSFA, g	3.37±0.31	1.36±0.14
ΣMUFA, g	2.68±0.10	2.47±0.17
ΣPUFA, g	0.44±0.04	2.53±0.19
PUFA:SFA ratio	0.13±0.03	1.86±0.05
Cholesterol, mg	39.02±0.91	30.5±0.79
Trans fats, g	0.18±0.03	not found
Table salt, g	2.50±0.50	0.98±0.19
Vitamin B_6, mg	0.32±0.06	1.38±0.35
Vitamin B_{12}, µg	1.44±0.11	1.98±0.67
Vitamin C, mg	0.30±0.07	45.50±10.47
Vitamin D_3, µg	0.08±0.03	8.57±1.71
Vitamin E, mg	0.24±0.01	2.75±0.41
Magnesium, mg	28.423±2.71	145.258±29.052
Calcium, mg	13.87±1.14	185.535±31.541

Table 4. Antioxidant capacity of the cutlet samples

Sample	OAE_{FRAP}, µmol eq quercetin/100 g of sample			
	0 days	3 days	14 days	28 days
Control cutlet	25.866 ± 0.330	25.228 ± 0.153	31.467 ± 0.554	33.268 ± 2.473
Test cutlet	232.754 ± 0.603	239.783 ± 0.726	228.058 ± 1.060	232.870 ± 0.385



A B

Different letters (a, b, c, d) denote statistically significant differences between the corresponding samples during storage at p <0.05.

Figure 1. Change in peroxide value (A) and acid value (B) during storage of control and test cutlets

in the range of 2.3–1.6. The test sample did not contain *trans* fats.

To determine the efficiency of the selected composition of vitamins and green tea extract in the product composition, we analyzed the antioxidant capacity of the test sample during its storage in comparison with the control sample (Table 4).

The results of the analysis of the antioxidant capacity of the test and control samples of the cutlets showed that the TAC of the test sample was 9 times higher than that of the control sample. No significant differences in the TAC were observed during the storage of the test sample. The addition of the antioxidant complex helped to maintain the high antioxidant capacity of the test sample during its storage.

The effect of the antioxidant complex on the inhibition of oxidative processes during the storage of the food is shown in Figure 1. The inhibition of oxidative processes is expressed by the changes in peroxide value (Fig. 1 (A)) and acid value (Fig. 1 (B)).

The data in Fig. 1 (A) showed that the peroxide values in the control sample were higher than in the test sample during the storage period. The increase in peroxide value at day 28 was 112% for control samples and 37.3% for the test samples.

The same tendency was detected for the acid value (Fig. 1 (B)), as an accumulation of low molecular weight fatty acids. At the end of the storage period, the acid value increased by 3.5 and 2.6 times in the control samples and test samples, respectively.

The different dynamics of changes in peroxide and acid values in the test and control samples is probably associated with a different fatty acid composition of the samples and the presence of antioxidants with high antioxidant capacity.

4. Conclusion

Taking into account modern recommendations for patients to reduce cardiac risk, a recipe for functional meat cutlets was developed. In order to prevent CVD and correct risk factors, SFAs in the developed food were substituted with PUFAs, the level of table salt was reduced, and biologically active substances with pronounced antioxidant properties were added. The introduction of the antioxidant complex also reduced the intensity of oxidative processes in cutlets. The food can be recommended for inclusion into diet as a source of complete protein, vitamins and minerals for the prevention of CVD.

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