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Natural Red Currant and Beet Juices As a Source of Natural Coloring Agents for Minced Meat Semi-Finished Products

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ABSTRACT:

Food additives have a direct impact on the development of the food market. The aim of this study was to develop recipes for minced semi-finished products colored and enriched with food coloring agents based on beet and red currant. Analysis of the biochemical composition of vitamins in minced meat with the coloring agents showed that the coloring with a mixture of dried red currant juice and beetroot contained more ascorbic acid (vitamin C – 1.12 mg/100 g) and β-carotene (vitamin A – 0. 49 mg/100 g) in comparison with the dried beet coloring (vitamin C – 0.98 mg/100 g), (vitamin A – 0.46 mg/100 g), but less in comparison with the red currant coloring (vitamin C – 1.68 mg/100 g), (vitamin A – 0.56 mg/100 g). Studies on minced meat with coloring agents for storage and heat treatment revealed that the coloring agent derived from dry beet juice is the most stable, but stabilizers are more appropriate, as they can reduce color changes by up to 30%. The studied coloring agents are recommended to be used for coloring raw chicken, beef, and pork minced meats.

Keywords: red currant juice, beet juice, coloring, meat semi-finished products, organoleptic properties, vitamins

1. Introduction

One of the primary objectives of the food industry is to enhance the country's global competitiveness on the world market. Animal products play an important role in addressing this objective (Abdumuminov, 2021).
One of the important organoleptic indicators of quality is the appearance and color of the finished product. Recently, food coloring has been widely used in the meat processing industry (Sunday *et al.*, 2022). Uncolored ingredients with low coloration such as protein-fat emulsions, pork skin stabilizers, protein preparations of animal and vegetable origin, hydrocolloids, fibers, poultry meat, and meat after mechanical processing are used in meat processing (Inguglia *et al.*, 2023). The classical method of salting with sodium nitrite does not permit the production of meat products with the typical pink color that consumers have come to expect. The use of sodium nitrite in meat processing has both positive and negative aspects (Ferysiuk and Wójciak, 2020).
The use of natural food colorings helps to improve the consumer properties, sensory characteristics and chemical and biological parameters of the product (Meletios *et al.*, 2022). Natural coloring agents demonstrate high functional activity (Zavorokhina, 2023). The use of natural coloring agents can contribute to the antioxidant properties of the finished product (Lis and Bartuzi, 2023). Natural food coloring improves the appearance of the finished product while also increasing its nutritional value (Imchen and Singh, 2023). Unfortunately, the quantity and range of natural food coloring agents is not sufficient to meet all the needs of the processing industry and the market. The replacement of natural coloring agents with synthetic ones can have a significant impact on human health (Melnikova *et al.*, 2019).
This study aimed to develop recipes for minced semi-finished products colored and enriched with food coloring agents derived from beet and red currant.

2. Materials and methods

Objects of research

The objects of research in this study were:
- dried red beet juice (TK Prestizh, Russia), dried natural red currant juice (TK Prestizh, Russia). Dry juices were used as a coloring agents.
- test semi-finished products from minced meat produced with the addition of dry juices.

The raw materials used in the study met the requirements of current regulatory documentation at the time of testing. The application dosages of dry juices were determined experimentally.
All glassware and reagents of chemical purity and above were purchased from Dia-M, Moscow, Russia.

Determination of coloring agents

The methodology for determining the content of coloring substances in dry juices is based on the comparison of the optical density of the coloring agent with a standard solution of cobalt sulfite. First, 20 g of crystalline cobalt sulfide was dissolved in distilled water, diluted, and brought to the mark in a 1000 mL volumetric flask. The optical density of the resulting solution was then measured. Then 1 g of the coloring agent was weighed and diluted in a 100 mL flask with distilled water. The obtained solution was poured into a 1000 mL volumetric flask. Then 40 mL of concentrated hydrochloric acid was added to the solution and diluted with distilled water to the mark. The optical density of the filtered liquid was measured on a Shimadzu spectrophotometer (Shimadzu, Kyoto, Japan) at 510 nm. The quantity of coloring agents was calculated according to the formula, taking into account the mass of the dye suspension and the optical densities of the solutions (Tereshchuk and Pechenik, 2019).

$$\frac{A_1}{A_2} = \frac{C_1}{C_2},$$

where A_1 – optical density of cobalt sulfate standard solution, A_2 – optical density of the tested coloring agent solution, C_1 – oenine concentration equal to 0.022 g in 1 L of standard solution, C_2 – pigment concentration in 1 liter of the coloring agent solution.

Definition of vitamin C

Determination of vitamin C content was performed according to Murry's method (Aristidou and Lasenby, 2009). A 5 g sample was ground in a mortar with 20 mL of 1% hydrochloric acid solution for 10 min, 1% oxalic acid solution was added. The flask was then shaken vigorously several times and allowed to stand for 15 minutes to precipitate the proteins. Titration was performed from a microtube with a 0.001 N solution of 2,6-dichlorophenolindophenolate sodium (Tillmans dye) until a stable pink color appeared. The amount of ascorbic acid was determined according to the formula:

$$X = \frac{100 \cdot a \cdot V \cdot T}{c \cdot b},$$

where X – ascorbic acid content in mg per 100 g of substance; a – amount of dye used for titration, mL; T – Tillmans dye titer (0.14); V – volume of the volumetric flask with extract; b – quantity of extract taken for titration, mL; c – sample of test material, g.

Definition of vitamin A

A sample of 0.2 to 1.0 g was taken and ground in a porcelain mortar with silica sand to break down the cell walls. Then $MgCO_3$ and 5-10 mL of acetone were added. Small portions of solvent were then injected until the material was completely discolored. The optical density of the extract was then determined on a Shimadzu spectrophotometer (Shimadzu, Kyoto, Japan) at wavelengths of 440, 644, 662 nm. The vitamin A (β-carotene) content Ccar was calculated according to the formula

$$C\ car = 4.7 \cdot E440 – 0.268 \cdot (5.134 \cdot E662 + 20.44 \cdot E644),$$

where E440 – optical density value at a wavelength of 440 nm; E662 – optical density value at a wavelength of 662 nm; E644 – optical density value at a wavelength of 644 nm.

Definition of vitamin B

A 1 g weight of the coloring agent was ground in a porcelain mortar and 15 mL of 0.1 n HCl solution was added. The mixture was then stirred and the resulting mass was transferred to a 100 mL heat-resistant flask, adding 0.1 n HCl solution until a volume of 75 mL was reached. The flask was placed on a water bath and incubated for 45 min, stirring occasionally. The optical density of the solution was measured on a Shimadzu spectrophotometer (Shimadzu, Kyoto, Japan) at a wavelength of 445 nm to determine the oxidized form of riboflavin.

Determination of color stability

For this purpose, a 5 g sample was added to a 100 mL flask, then covered with distilled water and kept at a temperature of 50 °C in a water bath. Then 2 mL of concentrated hydrochloric acid was added there, and then the optical density was measured for the filtered and cooled liquid on a Shimadzu spectrophotometer (Shimadzu, Kyoto, Japan) at 510 nm. Subsequent optical density determination was performed after two days, under the same conditions under which the initial value was measured. The change in optical density was then examined for 15 days, every 5 days, under the same conditions under which the initial value was measured.

Determination of color stability of dry juices during thermal treatment was also performed on a Shimadzu spectrophotometer (Shimadzu, Kyoto, Japan) in solution when heated to 50, 70, 100 °C (Chupakhina, 2019).

Statistical analysis

Statistical processing was performed using Excel 2019 (2019, Microsoft Company, Redmond, WA, USA) and IBM SPSS Statistics 22 (2013, SPSS: An IBM Company, Chicago, IL, USA).

3. Results and discussion

Samples of dried beet and red currant juices and semi-finished products were examined for the quantity of coloring substances (anthocyanins), vitamin C (ascorbic acid), vitamin B_2 (riboflavin), vitamin A (β-carotene)б and dry matter content.
Anthocyanin content was found to be 0.058 g/L in dried beet juice, 0.040 g/L in red currant juice, and 0.048 g/L in a mixture of beet and red currant juices. The dry matter content of beet juice was 91.00±0.05 % and that of red currant juice was 92.00±0.05 %.
The results for the vitamin content of the colored semi-finished products are presented in Table 1.
Table 1: Vitamin content in colored semi-finished products, % of daily requirement.

Semi-finished product with minced pork meat	**Quantity of vitamins mg/100g**		
	% of daily requirement		
Dried juice	C	A	B_2
RC	1.12	0.49	0.14
	1.63	9.20	9.20
C	0.98	0.46	0.23
	1.86	9.80	5.60
B+RC	1.68	0.56	0.19
	1.97	11.20	7.60

RC - red currant; B - beet
Analysis of the results of Table 1 showed that the highest amount of vitamin C (ascorbic acid) was found in samples of dried juice of red currant, the lowest – in beet (10.08 and 8.68 mg/100 g, respectively). In the samples of colored semi-finished products, the highest amount of vitamin C was found in minced pork with dried red currant juice – 1.68 mg/100 g.
The highest content of vitamin A (β-carotene) was found in samples of dried red currant juice, the lowest in beet – 2.27 and 1.46 mg/100 g, respectively. In samples of colored semi-finished products, the highest amount of vitamin A was found in minced pork with dried red currant juice – 0.56 mg/100 g.
The highest amount of vitamin B_2 (riboflavin) was found in samples of dried beet juice, the lowest in red currant juice – 0.88 and 0.54 mg/100 g, respectively. In the samples of colored semi-finished products, the highest amount of vitamin B_2 was found in minced pork with dried beet juice – 0.23 mg/100 g.
Other studies (Sentkowska and Pyrzyńska, 2023) found no significant differences in the content of vitamins and coloring substances in anthocyanin coloring agents compared to our findings in dried beet and red currant juice samples. It is worth noting that when liquid anthocyanin extracts were used, the proportion of ascorbic acid content increased by 20% compared to coloring samples in dry powder form, which increases the functional value of such food additive for the product.
Similarly, in composite blends of anthocyanins and carotenoids, 40% more vitamin A (β-carotene) was found, which also increased the functionality of the food additive (Carrillo *et al.*, 2022).
The applied dosages of dried juices per 20 g of minced chicken and beef and the coloring result on a five-point scale are presented in Table 2 and Figure 1.

Table 2: Dosages of dried juices in semi-finished products

No. of meat semi-finished product sample	**Dried juice**	
	RC	C
Minced chicken meat		
1	-	0.05
2	1.00	-
3	2.00	-

4	0.10	0.05
5	0.05	0.05
Minced beef meat		
1	-	0.05
2	2.00	-
3	0.05	0.20
4	0.05	0.05

RC - red currant; B - beet

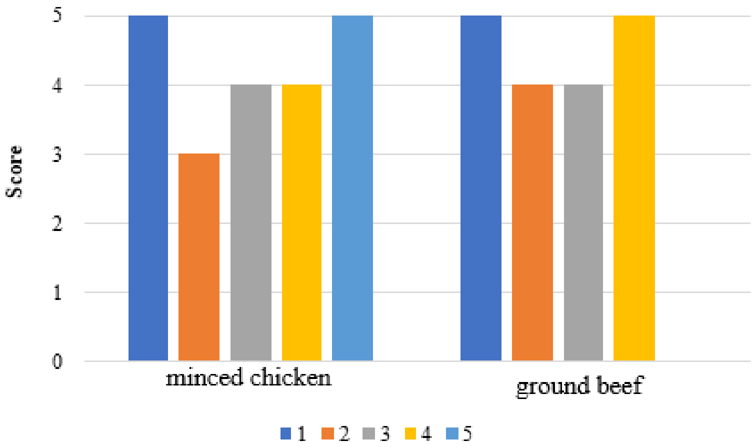

Figure 1: Evaluation of the appearance of the colored meat semi-finished product: 1 – sample No.1; 2 – sample No.2; 3 – sample No.3; 4 – sample No.4; 5 – sample No.5.

The dried juices of red currant and beet were examined for color intensity. Based on the results of coloring chicken and beef minced meat with dried red currant and beet juices, it was decided to use dried beet juice and a mixture of dried red currant and beet juices in equal proportions. The following dosages of coloring agents (dry juices) were selected and the following formulations were made:

1) 250 g of dried beet juice per 100 kg of minced meat;

2) 250 g of dried beet juice and 250 g of dried red currant juice per 100 kg of minced meat.

Based on the results of evaluating the appearance of samples of colored beef and chicken minced meat on a five-point scale, the highest score (5 points) was given to samples of minced meat with 0.05 g of dry beet juice and a mixture of 0.05 g of red currant and 0.05 g of beet, and the lowest score (3 points) was given to a sample of chicken minced meat with 1 g of dry red currant juice.

The food additives used to stabilize the color of colored minced meat products (20 g) were citric acid (0.02 g), sodium erythorbate (0.002 g), and sodium nitrite (0.002 g).

Since the samples of colored minced meat showed significant changes during prolonged storage, it was decided to add food additives to stabilize the color: citric acid (E330), sodium erythorbate (E316), sodium nitrite (E250) in the amounts of 0.02 g, 0.002 g, and 0.002 g, respectively (Table 3).

Table 3:Changes in optical density of colored semi-finished products with the use of stabilizers during 15 days of storage (t=2-4°C)

Semi-finished minced pork product		**Shelf life, days**				**Changes in 15 days, %**
Dried juice	**Food additive**	**0**	**5**	**10**	**15**	
RC	E316	0.249	0.218	0.192	0.168	32.5
B	E316	0.203	0.178	0.158	0.139	31.5
RC	E330	0.225	0.182	0.141	0.107	52.5
B	E330	0.232	0.192	0.146	0.110	52.0
RC	E250	0.225	0.191	0.158	0.121	46.0
B	E250	0.264	0.222	0.183	0.144	45.5

RC - red currant; B - beet

As a result of storage of chicken and beef semifinished products colored with dried juices, insignificant changes in color and optical density of not more than 15% were observed. The samples of minced chicken meat that were colored with a mixture of beet and red currant juices performed the best. In turn, significant changes from 57% to 61% were observed with extended storage time. The worst performing samples were those of minced pork with dried red currant juice, and the best performing samples were those of minced pork with a mixture of dried beet and red currant juices.

Sodium erythorbate E316 worked best as a stabilizer, with changes ranging from 31.5 to 32.5% in 15 days. Citric acid was the worst performer, with almost no increase in shelf life observed with its use (52.0-52.5%). Average changes were also observed when sodium nitrite was applied (45.5-46.0%).

Beef and chicken minced meat samples colored with dried beet and red currant juices when heated to 70 ℃ or 100 ℃ were also observed. The results are summarized in Table 4.

Table 4: Changes in optical density of colored semi-finished products after heat treatment (t=70 ℃ and 100 ℃)

Semi-finished product		**Heat treatment**				
Minced meat	Dried juice	Control	70 ℃	Changes, %	100 ℃	Changes, %
chicken	B	0.215	0.155	28	0,147	32
chicken	RC	0.213	0.152	29	0,142	33
chicken	B+RC	0.221	0.168	24	0,161	27
beef	B	0.219	0.164	25	0,153	30
beef	RC	0.217	0.152	30	0,145	33
beef	B+RC	0.224	0.165	26	0,158	29

Control – before heat treatment. RC – red currant; B – beet

Beef and chicken minced meat samples colored with samples of dried beet and/or red currant juices when heated to 70 and 100 ℃ were also observed. Overall, there was little change in the range of 24-33%. The smallest fluctuations were observed when the samples were heated up to 70 ℃, while the largest fluctuations were observed at 100 ℃. The minced meat samples colored with a mixture of dried juices of beet and red currant (24-29%) performed best. The least stable were the samples colored with dried red currant juice (29-33%).

The study investigated the change in the characteristics of coloring agents from concentrates of cranberry, raspberry, lingonberry, and red currant berries. A decrease in optical density was observed upon heating (Kandemir *et al.*, 2022). Short-term heating led to a decrease in coloring substances due to an increase in the rate of oxidation and polycondensation of polyphenolic fragments. Increasing heating time also decreased the optical density, indicating a decrease in coloring substance content (Drohsler *et al.*, 2021).

Comparison of changes in optical density of berry concentrates showed minimal loss of optical density in cranberry concentrate samples at different heating levels, indicating the least loss of coloring agents in cranberries (Elferjane *et al.*, 2024). When heated to 80 ℃, the amount of coloring substances in cranberry and lingonberry concentrates was preserved up to 80 % when exposed to temperature for 4 h. When heated to 100 °C, the coloring substance content decreased 2.0-fold in cranberry concentrate and 1.4-fold in lingonberry concentrate after 5 hours. In raspberry and red currant concentrates, coloring substance loss at minimum temperature was 40% and at higher temperature was 70% and 82%, respectively (Iñiguez-Moreno *et al.*, 2023).

4. Conclusion

Thus, the analysis of the biochemical composition on the vitamins of minced meat with coloring agent showed that the coloring agent with a mixture of dried red currant and beet juices contained more ascorbic acid (vitamin C – 1.12 mg/100 g) and β-carotene (vitamin A – 0.49 mg/100 g) in

comparison with the coloring agent from dried beet (vitamin C – 0.98 mg/100 g), (vitamin A – 0.46 mg/100 g), but less in comparison with the coloring agent from red currant (vitamin C – 1.68 mg/100 g, vitamin A – 0.56 mg/100 g). Based on the evaluation of the appearance of colored semi-finished products, the ratio of dried red currant and beet juice for coloring was determined.
Studies of minced meat with coloring agents during storage and heat treatment showed that the most stable is a coloring agent from dried beet juice, but it is more appropriate to use stabilizers, they can reduce color changes up to 30%. Sodium erythorbate proved to be the best of the studied stabilizers.
The possibility of using natural coloring agents from dried juice of beet and/or red currant for meat semi-finished products has been proved. The studied coloring agents are recommended to be used for coloring raw chicken, beef, and pork minced meat, as well as in the production of raw smoked sausages.

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Conflict of Interest declaration
The authors declare that they have NO affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

Author Contributions
Olga Babich, Stanislav Sukhikh contributed to the design and implementation of the review, writing the original draft and editing; Olga Kriger and Alexandra Maidanova methodology, of the research. All authors accepted the final draft.

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