

OPTIMIZING COMPONENT COMPOSITION OF FUNCTIONAL FOODS WITH BENEFICIAL EFFECTS ON THE CARDIOVASCULAR SYSTEM

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Abstract

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The raw materials included in the food formulas with beneficial effects on the cardiovascular system were selected based on literary sources. The content of the biologically active substances - functional components in the raw materials - anthocyanins, polyphenols and their antioxidant activity were used to draw mathematical models for optimal component composition of the feedstock - blueberries, raspberries, sour cherries. The experiment design was made by using simplex lattice (second degree) for a ternary system. Quantitative blueberries, raspberries, sour cherries and their anthocyanins, polyphenolic substances contain and antioxidant activity were involved in a composition. The models were used to obtain functional foods containing the listed biologically active substances and antioxidant activity. After applying the appropriate process technology, they retained its functional properties.

Key words: anthocyanins, polyphenols, antioxidant activity, cardiovascular disease, mathematical models, functional foods

Abridgments: BAS - biologically active substances, ANTH – anthocyanins, ANT – antioxidants, TPF – total polyphenolic substances, ORAC - antioxidant activity

Introduction

There are numerous studies of raw materials natural sources of BAS that directly or like extracts in various combinations give the ability to create formulas. Well-selected and applied technology is a prerequisite for obtaining functional foods with beneficial effects on human health.

The blueberries, the raspberries and the sour cherries are rich in both essential nutrients and secondary metabolites (polyphenols and flavonoids), which have antioxidant, anti-inflammatory, anti-tumor effect (Zheng and Wang, 2003). They have beneficial effects on the cardiovascular system, bones and immune system to tumor pathogenic changes in the human body (Seeram et al., 2006; Whitson et al., 2004).

The blueberries there are positive role in the human health and disease prevention. Their protective effect is generally attributed to polyphenolic substances - anthocyanins, flavan-3-ols, flavonols, and proanthocyanidins, which determine their high antioxidant effect (Cho et al., 2004; Hou, 2003; Pellegrini et al., 2003; Prior et al., 2001; Wu et al., 2004; Zafra-Stone et al., 2007).

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The ANTH antioxidant effect and beneficial effect on human health is correlated with their content (Moyer et al., 2002; Rosse and Kasum, 2002). The ANTH combination show higher free radical scavenging activity compared with purified pigments in the same amount (Stinzing et al., 2002).

Rich in fruit and vegetables diets, which increase intake of PF and other ANT lead to cardiovascular disease protection (Booth et al., 2006). American Dietetic Association defines functional foods as “completed, enhanced or fortified foods” that could be consumed as part of a varied diet on a regular basis to achieve the potential health benefits. As an example of comprehensive non-modified foods are fruit and vegetables - the simplest form of functional foods. The new in functional foods is mostly in the way in which essential nutrients with beneficial effect are included in the delicious and healthy food that is patented, has a health mark. Consequently, each nutrient with proven quality could be included

in the foodstuff, but it must retain its functional properties (Harper, 1999).

This work is aimed at developing the mathematical models for optimal component composition of functional foods based on ANTH and PF content and ORAC of blueberries, raspberries and sour cherries by using traditional and non-traditional native rich in BAS raw materials.

Materials and Methods

Traditional and non-traditional raw materials: blueberries, raspberries and sour cherries, native rich in BAS: ANTH, PF and high ORAC were used in development of mathematical models for finding the optimal component composition of functional foods with high biological value (Denev et al., 2009), (Table 1).

The surface reflectance in triangular coordinate system is plotted based on the mathematical models. The factor values are plotted on the side of an equilateral triangle in a uniform scale from 0 to 1. By setting different values of x_1 , x_2 and x_3 could be defined for each point in the triangle, which corresponds to the specified mixture composition what is the content of the ANTH, TPF and ORAC respectively.

The experiment design was made by using simplex lattice (second degree) for a ternary system - x_1 , x_2 , x_3 , (Vuchkov and Stoyanov, 1986) and is presented in Table 2.

The target functions for optimization are defined in literature data for the ANTH, PF content and ORAC of blueberries, raspberries and sour cherries (Denev et al., 2009).

Results and Discussion

Using the simplex method and the related modeling and optimization procedures are obtained mathematical models for the components concentration in the mixture - ANTH, TPF and ORAC as follows:

Anthocyanins content

$$\text{ANTH} = 2131.81 \cdot X_1 + 1469.51 \cdot X_2 + 2641.71 \cdot X_3, \mu\text{g}\cdot\text{g}^{-1} \quad (1)$$

Total polyphenolic substances content

$$\text{TPF} = 8718.1 \cdot X_1 + 4751.4 \cdot X_2 + 9094.7 \cdot X_3, \mu\text{g}\cdot\text{g}^{-1} \quad (2)$$

Table 1
Biologically active substances content in the raw materials

Raw materials	Biologically active substances		
	Anthocyanins, $\mu\text{g}\cdot\text{g}^{-1}$	Polyphenols, $\mu\text{g}\cdot\text{g}^{-1}$	Antioxidant activity, $\mu\text{mol}\cdot\text{g}^{-1}$
Sour cherries (X_1)	2131.8	8718.1	58.6
Raspberries (X_2)	1469.5	4751.4	38.9
Blueberries (X_3)	2641.7	9094.7	96.0

Antioxidant activity

$$\text{ORAC} = 58.6 \cdot X_1 + 38.9 \cdot X_2 + 96.0 \cdot X_3, \mu\text{mol}\cdot\text{g}^{-1} \quad (3)$$

The obtained equations describe the accuracy of the change in concentration of the dependent variables at $P < 0.05$, $R > 0.9$.

The surface reflectance of the ANTH and TPF content and ORAC in the component mixture are shown in Figures 1, 2 and 3 respectively.

Based on the surfaces reflectance could be concluded that there are the highest ANTH content - over 2000 $\mu\text{g}\cdot\text{g}^{-1}$, TPF content - over 7000 $\mu\text{g}\cdot\text{g}^{-1}$ and the highest ORAC - over 60 $\mu\text{mol}\cdot\text{g}^{-1}$ when in the ternary composition dominates component x_3 (blueberries).

For optimization of the ternary mixtures obtained from raw materials - blueberries, raspberries and sour cherries are accepted the following boundary conditions:

$$\text{ANT} > 2000 \mu\text{g}\cdot\text{g}^{-1}$$

$$\text{TPF} > 7000 \mu\text{g}\cdot\text{g}^{-1}$$

$$\text{ORAC} > 60 \mu\text{mol}\cdot\text{g}^{-1}$$

The outlined area ABCD (Figure 4) is adopted for the optimum in which the content of ANTH, TPF and ORAC range from 2400 to 2600 $\mu\text{g}\cdot\text{g}^{-1}$, from 8000 to 9000 $\mu\text{g}\cdot\text{g}^{-1}$ and from 70 to 95 $\mu\text{mol}\cdot\text{g}^{-1}$ respectively. Each point of this area correspond to relevant component composition, whose the values for the ANTH, TPF content and ORAC are optimized.

Table 2
Simplex lattice

Number	X_1	X_2	X_3
1	1	0	0
2	0	1	0
3	0	0	1
4	0.5	0.5	0
5	0.5	0	0.5
6	0	0.5	0.5
7	0.33	0.33	0.33
8	0.25	0.5	0.25
9	0.5	0.25	0.25
10	0.25	0.25	0.5
11	0.5	0.5	0

Based on mathematical models are composed of the following functional food and beverage formulas with initial compo-

sition of raw materials - sour cherries, raspberries, blueberries and optimized composition of ANTH, TPF, ORAC, (Table 3):

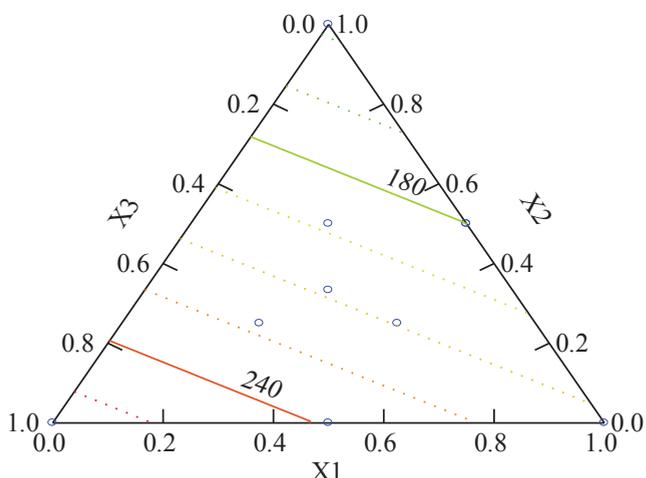


Fig. 1. The surface reflectance of the anthocyanins content in the component mixture

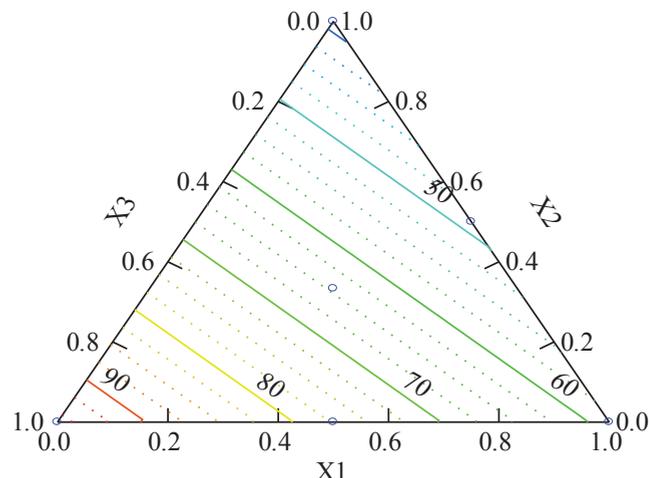


Fig. 3. The surface reflectance of the antioxidant activity in the component mixture

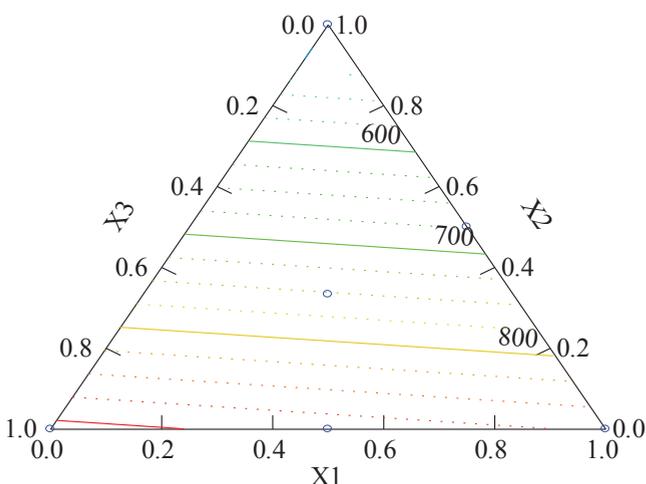


Fig. 2. The surface reflectance of the total polyphenolic substances content in the component mixture

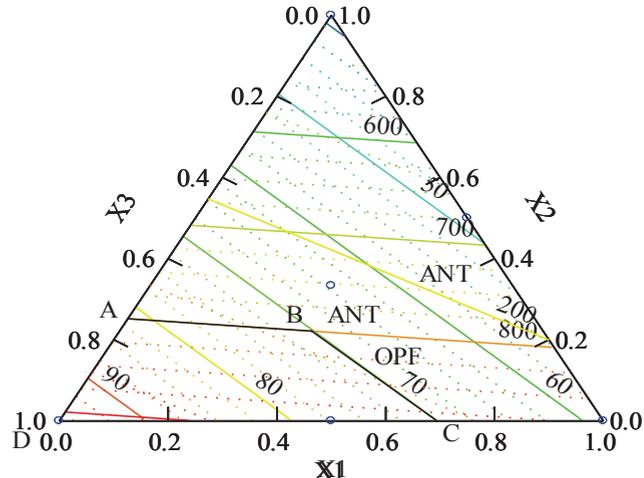


Fig. 4. Optimization of a ternary mixture of fruit products in anthocyanins, total polyphenolic substances content and antioxidant activity

Table 3
Formulas of functional foods and beverages

Variant	Sour cherry, g.kg ⁻¹	Raspberry, g.kg ⁻¹	Blueberry, g.kg ⁻¹	Anthocyanins, μg.g ⁻¹	Polyphenols, μg.g ⁻¹	Antioxidant activity, μmol.g ⁻¹
1	100	50	850	2532.10	8839.87	89.405
2	700	50	250	2226.16	8613.91	66.965
3	100	250	650	2297.66	7971.21	77.985
4	700	250	50	1991.72	7745.25	55.545
5	400	150	450	2261.91	8292.56	72.475

Conclusions

Mathematical models for optimal composition of functional food formulas for the cardiovascular system on basis blueberries, raspberries and sour cherries in terms the content of anthocyanins, polyphenol substances and antioxidant activity are developed.

The optimal area of functional foods on basis blueberries, raspberries and sour cherries, which ensures maximum contents of anthocyanins, polyphenols and antioxidant activity, is determined.

Formulas of functional foods and beverages with initial composition of raw materials – sour cherries, raspberries, blueberries and optimized composition of anthocyanins, total polyphenols and high antioxidant activity are developed.

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