Scientific Papers. Series D. Animal Science. Vol. LXVIII, No. 1, 2025
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

ASSESSMENT OF NUTRITIONAL AND FUNCTIONAL PROPERTIES OF YOGURT ENRICHED WITH ARONIA POMACE POWDER

Andreea-Bianca BALINT[1], Florina STOICA[2], Ioana Cristina CRIVEI[1], Ionuț Dumitru VELEȘCU[1], Roxana Nicoleta RATU[1], Marius Giorgi USTUROI[3]

[1]Faculty of Agriculture, Department of Food Technologies, “Ion Ionescu de la Brad” Iasi University of Life Sciences, 3 Mihail Sadoveanu Alley, 700489, Iasi, Romania
[2]Research Institute for Agriculture and Environment, “Ion Ionescu de la Brad” Iasi University of Life Sciences, 700490, Iasi, Romania
[3]Department of Animal Resources and Tehnologies, Faculty of Food and Animal Sciences “Ion Ionescu de la Brad” Iasi University of Life Sciences, 700490, Iasi, Romania

Corresponding author email: roxana.ratu@iuls.ro

Abstract

Aronia pomace powder, obtained as a by-product of juice production through pulp exhausted, is rich in bioactive compounds like anthocyanins, flavonoids, and polyphenols, known for their antioxidant and health-promoting properties. Incorporating aronia pomace powder (APP) into yogurt at 4% and 6% levels offers a novel approach to enhancing its nutritional, sensory, and functional attributes. This study evaluated the effects of Aronia powder on yogurt's physicochemical properties, phytochemical profile, texture, color and sensory acceptability. APP-enriched yogurts exhibited increased total phenolic content (2.50-2.94 mg GAE/g) and antioxidant activity (17.47-19.27 µmol Trolox/g), alongside a visually appealing reddish-purple color due to anthocyanins. The sensory evaluation highlighted 6% APP as the optimal concentration, balancing taste and nutritional benefits. Furthermore, APP demonstrates significant potential for the development of functional dairy products, aligning with consumer preferences for health-oriented and sustainable options.

***Key words**: antioxidants, Aronia by-products, functional dairy products, polyphenols, value-added ingredient.*

INTRODUCTION

The demand for functional foods with health benefits has risen, with fruit-enriched dairy products being among the most popular due to their bioactive content and consumer preference (Rincón-León, 2003). Berries such as blackberries, raspberries, black currants, blueberries, and elderberries are rich in phenolic compounds and fiber, making them ideal for incorporation into dairy products like kefir, yogurt, and fermented milk (Ozdemir & Ozkan, 2020).

The use of fruit pomace enhances the circular economy, while natural antioxidants align with the clean label trend (Raikos et al., 2018). The nutritional value and bioactivity of yogurt are further improved by adding fruit and fruit juices (Dimitrellou et al., 2020; Plessas et al., 2024). Yogurt, known for its nutritional and sensory qualities, has been widely studied for functional enhancements, benefiting both the dairy industry and consumers by extending shelf life and offering higher energy and superior sensory profiles (Kowaleski & Battestin, 2020). The fortification of yogurt with bioactive a superfood with strong antioxidant qualities, Aronia (*Aronia melanocarpa*) berries, also known as black chokeberries, contain many bioactive compounds, including anthocyanins, carotenoids, fatty acids, flavonoids, phenolic compounds, and vitamins. The fruit has recently attracted attention because of its powerful antioxidant activities (Peng et al., 2022). Aronia pomace powder (APP), derived from aronia juice processing, contributes to functional food development and circular economy (Lazăr & Catană, 2020).

We anticipate that adding powdered aronia pomace to yogurt will enhance dietary fiber and polyphenol intake, lower fat content without altering texture, and ensure product atractivity. This study evaluates the impact of 4% and 6% APP supplementation on yogurt's physicochemical, textural, antioxidant, and sensory properties.

MATERIALS AND METHODS

According to the research methodology, the first stage included qualitative evaluations of the powder from a phytochemical point of view and of the raw material - in this case, milk. The final products were analyzed from a chemical, phytochemical, physical and sensory point of view and the technological processes involved in the production of yogurt were described.

According to the research methodology, the first stage included qualitative evaluations of the powder from a phytochemical point of view. The final products were analyzed from a chemical, phytochemical, physical, textural and sensory point of view and the technological processes involved in the production of yogurt were described.

Obtaining powder from Aronia pomace powder

To obtain *Aronia melanocarpa* chokeberry powder, the fruits were washed, squeezed and the resulting chokeberry dried at +42°C to protect the bioactive compounds (anthocyanins, flavonoids, polyphenols). Once dried, the chokeberry was ground and turned into a fine powder using a high-speed grinder.

The **total anthocyanin content** was determined using the modified pH differential method described by Lipsa et al. (2024). Samples were diluted at a 1:10 ratio, and a reaction mixture consisting of 200 µL vegetable extract and 800 µL buffer solution (pH 1.0/4.5) was prepared. Absorbance was measured at 520 nm and 700 nm using a UV-Vis spectrophotometer (Analytik Jena-Specord 210 Plus, Jena, Germany). The results were expressed as milligrams of cyanidin-3-glucoside (C3G) per gram of dry matter (dm).

The **total flavonoid content** was determined using the aluminum chloride spectrophotometric method described by Lipsa et al. (2024). The reaction mixture consisted of 0.25 mL extract, 2 mL distilled water, and 0.075 mL 5% sodium nitrite, followed by the addition of 0.15 mL aluminium chloride after 5 minutes and 0.5 mL 1 M sodium hydroxide after 6 minutes. Absorbance was measured at 510 nm using a UV-Vis spectrophotometer (Analytik Jena Specord 210 Plus, Germany). The total flavonoid content was expressed as mg catechin equivalents per gram (mg CE/g dm), based on a calibration curve (0.1-0.5 mg/mL, R^2 = 0.997).

The Folin-Ciocalteu method (Gavril et al., 2024) combined with spectrophotometric analysis was used to determine **the total polyphenol content** of the extract. The reaction mixture, consisting of 200 µL extract, 1 mL Folin-Ciocalteu reagent, 15.8 mL distilled water, and 3 mL 20% Na_2CO_3, was incubated for 60 minutes in the dark at room temperature. Absorbance was measured at 765 nm using an Analytik Jena Specord 210 Plus UV-VIS spectrophotometer (Germany). Polyphenols content was expressed as mg gallic acid equivalents per gram (mg GAE/g dm), based on a calibration curve (0.1-0.5 mg/mL, R^2 = 0.984).

The antioxidant activity of the extract was evaluated using the DPPH radical scavenging method, following the protocol of Lipsa et al. (2024). A reaction mixture containing 100 µL extract and 3.9 mL of 0.1 M DPPH solution was incubated in darkness at +25°C for 30 minutes. Absorbance was measured at 515 nm using a UV-Vis spectrophotometer (Analytik Jena-Specord 210 Plus, Germany). A control sample, consisting of 3.9 mL of 0.1 M DPPH solution and 100 µL methanol, was prepared under identical conditions. Antioxidant activity was expressed as µmol Trolox/g dm, based on a calibration curve

Preparation and caracterization of supplemented yogurt

The functionality of enriched yoghurt was assessed by incorporating Aronia pomace powder (APP) at two specific concentrations: 4% and 6%. A control group consisting of yoghurt without APP addition was also prepared for comparison. The selection of the 4% and 6% APP concentrations was guided by prior sensory evaluations conducted by a panel of experts, which identified these levels as optimal in terms of visual appeal, texture, flavour, and colour. The technological process for producing the enriched yoghurt is illustrated in Figure 1. The yoghurt production process involved the reception and filtration of raw milk, followed by pasteurization at 90°C for 30 minutes to ensure microbiological safety. After cooling to 45°C, starter cultures (*Streptococcus thermophilus* YF-L81 and *Lactobacillus delbrueckii* subsp. *bulgaricus*) were inoculated, initiating fermentation. *Aronia melanocarpa* powder was added to develop YAPP4 (4% APP), YAPP6 (6% APP), and YM (without APP). The mixtures were thermosealed at 227°C and fermented at 43°C, facilitating lactose conversion. Post-fermentation, the yoghurt was cooled (20°C → 3°C) and stored at 3°C, preserving stability and sensory attributes. The enriched yoghurt was assessed for physicochemical parameters (fat, protein, ash, moisture, total dry matter, carbohydrates), using AOAC 2000 methods.

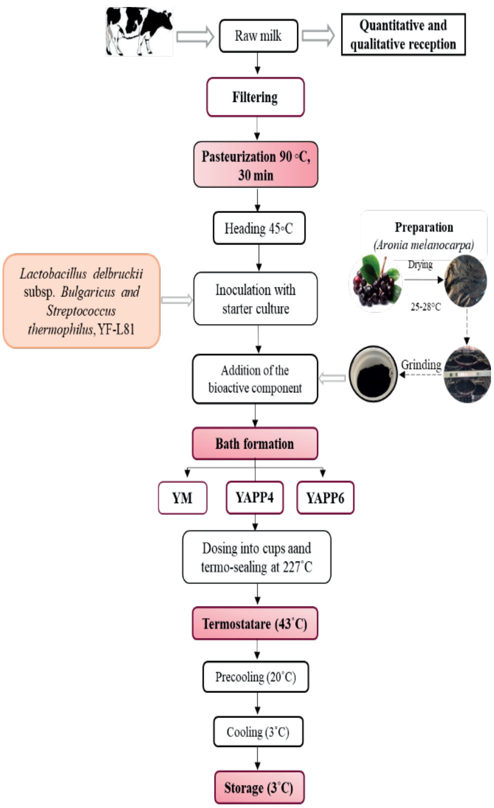

Figure 1. Functional yogurt prototype processing flow diagram (own source)

Phytochemical characterization of supplemented yogurts

The anthocyanin, flavonoid and phenolic content, as well as the antioxidant activity of APP-enhanced yogurt were evaluated using the procedures described above.

Color assessment of supplemented yogurts

According to Dag et al. (2017), the CIELAB system (L*, a*, b*) with a MINOLTA Chroma Meter CR-410 (Konica Minolta, Osaka, Japan) was used to analyze the color characteristics of Aronia pomace and APP enhanced-yogurts. To provide insight into the visual consequences of APP enrichment, L* denotes brightness, a* measures red-green tones, and b* depicts yellow-blue tones.

Textural parameters of supplemented yogurts

A Mark 10 ESM 300 texturometer (New York, NY, USA) fitted with a 5-50E series digital dynamometer (resolution: 0.05 N) was used to analyze the texture of enhanced yogurt samples.

Sensory evaluation of supplemented yogurts

The sensory evaluation process was conducted in strict accordance with the guidelines set in ISO 13299.

RESULTS AND DISCUSSIONS

With a high concentration of phenolic compounds and strong antioxidant activity, aronia powder has a complex phytochemical profile that makes it a useful component of nutraceuticals and functional foods. As presented in Table 1, its antioxidant and anti-inflammatory properties are attributed to the presence of flavonoids (9.85 ± 0.36 mg EC/g) and total anthocyanins (1.08 ± 0.02 µg/g), while total polyphenols (20.89 ± 0.12 mg) improve cellular protection and oxidative stability. Its high antioxidant activity (87.5 Trolox equivalents) further supports its nutritional and physiological significance by confirming its potential to scavenge free radicals. Anthocyanin content affects the powder's red color, as shown by a positive a value* in colorimetric analysis, whereas a yellow undertone* is suggested by the b parameter. The red-yellow color profile that is typical of anthocyanins is confirmed by the plotting of the combined +a and +b values** in the first quadrant. These results emphasize the dual benefits of Aronia powder as a natural colorant and a potent antioxidant source, which makes it a great option for food compositions that promote health.

Tabel 1. Phytochemical content and color parameters of the APP

Parameters		APP
Total Anthocyanins, µg/g dm		1.08±0.02
Total Flavonoids, mg CE/g dm		9.85±0.36
Total Polyphenols, mg GAE/g dm		20.89±0.12
Antioxidant Activity (DPPH)	µmol Trolox/g d.m	23.63±0.11
	Inhibition, %	87.54±0.36
L*		24.095±0.20
a*		12.635±0.05
b*		3.43±0.07

Yogurt's physical and nutritional qualities were improved by the substantial physicochemical changes brought about by the inclusion of aronia pomace, as detailed in Table 2. The increase in pH suggests low acidity, probably caused by interactions between phenolic compounds and lactic acid bacteria during fermentation The nutritional enrichment was confirmed by the nearly twofold increase in protein content (5.64%) and the rise in fat content from 4.26% (YM) to 5.48% (YAPP 6%). The fiber content increased from 0% (YM) to 3.83% (YAPP 6%), which may have functional advantages. Consistent mineral retention was indicated by the steady levels of carbohydrates (5.1%) and ash content (0.93% to 0.98%). Texture and stiffness were enhanced by the moisture reduction (84.99% to 78.89%), which also increased total dry matter (13.01% to 21.06%). Furthermore, the product's increased nutritional density was reflected in the energy value, which increased from 69.62 kcal/100 g (YM) to 100.14 kcal/100 g (YAPP 6%). According to these results, yogurt with aronia is a functional ingredient that is nutritionally superior due to its higher protein, fiber, and bioactive content.

In Table 3, it can be seen that the bioactive chemical profile of yogurt was significantly improved by enriching it with 4% and 6% aronia pomace, as shown by the notable rise in anthocyanin content from 0.76 to 1.16 µg/g and flavonoid concentration from 0.49 to 2.08 mg CE/g dm.

Table 2. Physical-chemical composition of plain enhanced yogurt

Physical-chemical characteristics	YM	YAPP4	YAPP6
pH	4.59±0.06	5.10±0.02	5.52 ±0.01
Fat, %	4.26±0.03	4.34±0.09	5.48±0.016
Protein, %	2.59±0.02	4.66±0.05	5.64±0.06
Carbohydrates, %	5.23±0.03	5.08±0.04	5.13±0.05
Fibre, %	-	1.95±0.07	3.83±0.12
Ash, %	0.93±0.01	0.94±0.08	0.98±0.12
Moisture, %	86.99±0.21	82.99±0.23	78.94±0.34
Total dry matter, %	13.01±0.03	16.97±0.04	21.06±0.07
Energetic value, kcal/100 g	69.62±0.02	81.92±0.03	100.14±0.02

Table 3. Phytochemical profile of plain and enhanced yogurts

Yogurt samples	Total anthocyanins, µg/g dm	Total flavonoids, mg CE/g dm	Total polyphenols, mg GAE/g dm	Antioxidant activity (DPPH)	
				µmol Trolox/g dm	Inhibition, %
YM	-	0.49±0.02	0.81±0.04	6.53±0.12	7.38±0.08
YAPP4	0.76 ±0.05	1.64 ±0.02	2.50 ±0.02	17.47±0.19	29.00±0.32
YAPP6	1.16 ±0.01	2.08 ±0.03	2.94 ±0.03	19.27±0.20	32.09±0.33

This implies that these physiologically active substances, which are well-known for their antioxidant and health-promoting qualities, are abundant in the added aronia powder. It's interesting to note that the highest total polyphenol content was at 6% addition (2.94 mg GAE/g dm), followed by 4% addition (2.50 mg GAE/g dm) in comparison to plain yogurt (0.81 mg GAE/g dm). This variation suggests possible interactions between the yogurt matrix and polyphenols. Most significantly, the addition of aronia powder resulted in a significant rise in antioxidant activity, with values increasing from 7.38% to 32.09%, indicating the enriched yogurt's functional potential. Although the antioxidant effects are maximized at 6% addition, more research is needed to increase product stability and sensory acceptability in order to guarantee its feasibility for commercial uses. Our results were in line with flavored yogurts that also contained edible plant components high in anthocyanins, such as roselle (Leyva et al., 2013) and grape pomace (Demirkol et al., 2018) in their composition. These useful food pigments were added to yogurt for research since it has a low pH and promotes anthocyanin content.

Color is a key physical determinant of a dairy's quality. The results of measurements of the samples' hue angle, chroma, and color parameters L*, a*, and b* are shown in Table 4.

Table 4. Color parameters of plain and enhanced yogurts

Parameters	YM	YAPP4	YAPP6
L*	94.75±0.02	59.79±0.05	40.74±0.09
a*	-9.35±0.09	14.47±0.22	20.97±0.27
b*	16.58±0.14	21.25±0.29	31.14±0.32

The addition of aronia powder to the yogurt matrix resulted in notable chromatic parameter changes in the CIELab* system, including a notable drop in lightness (L*) from 94.75 (YM) to 59.79 (YAPP4) and 40.74 (YAPP6), indicating an intensification of the product's dark color. Anthocyanin pigments are responsible for the accentuation of the reddish hues, as seen by the concurrent rise in the a* component value from -9.35 (YM) to 14.47 (YAPP4), and 20.97 (YAPP6). Meanwhile, a drop in the yellow tones is indicated by the b* values going from 16.58 (YM) to 21.25 (YAPP4) and 31.14 (YAPP6), which further supports the red-bluish spectrum's dominance. The final product's visual attractiveness and sensory perception are affected by these chromatic fluctuations, which are directly connected to the amount of aronia pomace utilized. Our results were consistent with those of the study by Postolache et al. (2023).

The results of the texture profile analysis are shown in Table 5. The most important factor in establishing the texture of yogurt is its hardness. It measures the yogurt's hardness and is thought of as the force needed to cause a specific deformation. As the concentration of the additional powder increased, so did the hardness of the yogurt augmented with the addition. Because of its higher water-holding capacity, the dietary fiber from aronia powder may absorb more moisture, increasing the samples' hardness. These alterations could be linked to the high water absorption capacity of the powder fibers and interactions between lactic proteins and aronia bioactive chemicals. In contrast to the control sample, the yogurts enriched with Aronia pomace showed increased hardness, gumminess, cohesiveness, and adhesiveness and decreased springiness.

Table 5. Textural parameters of plain and enhanced yogurts

Textural Parameters	Sample	Value
Cohesiveness	YM	0.29±0.00
	YAPP4	0.35±0.01
	YAPP6	0.36±0.01
Springiness	YM	0.50±0.02
	YAPP4	-0.02±0.00
	YAPP6	-0.28±0.01
Hardness, N	YM	5.65±0.00
	YAPP4	15.68±0.02
	YAPP6	19.77±0.02
Gumminess, N	YM	1.63±0.01
	YAPP4	5.22±0.03
	YAPP6	6.36±0.04
Adhesiveness, mJ	YM	−2.51±0.01
	YAPP4	-29.56±0.01
	YAPP6	-47.70±0.00

The effect of aronia on sensory qualities as appearance, color, scent, taste, odor, and general acceptability is demonstrated by the hedonic evaluation of yogurts enhanced with aronia powder (YAPP4 and YAPP6) in comparison to the control (YM). From Figure 2, we can deduce that yogurts YAPP4 and YAPP6 both scored lower on apperence and color, suggesting that aronia's high pigmentation affects how the eye perceives it. The presence of phenolic chemicals, which can impart bitter or astringent overtones, is probably the reason why YAPP6 had a far lower taste score than YM. Furthermore, YAPP6 showed decreased consistency, indicating that texture is influenced by polyphenol-protein interactions. However, both YAPP4 and YAPP6 gave scent and odor high ratings, suggesting that aronia supplementation had no detrimental effects on these qualities. Moreover, YAPP4 was favored above YAPP6, indicating that altering the amount of Aronia powder could improve sensory balance.

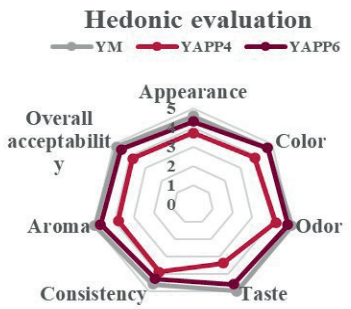

Figure 2. Comparative chart of the sensory attributes

CONCLUSIONS

APP has shown itself a bioactive ingredient when added to yogurt formulations, providing both functional and sensory advantages. Yogurt's total phenolic content and antioxidant capacity are greatly increased by APP addition compared to the control sample. Although increased APP concentrations may affect flavor and texture, sensory data indicates that consumers generally still find by-products enhanced yogurts to be satisfactory.

APP also offers the dairy industry a good source of anthocyanins, which makes it possible to create novel and health-promoting functional yogurts. To find the right incorporation levels and strike the perfect balance between nutritional advantages and sensory acceptability, more research is necessary.

Furthermore, the use of APP supports the development of eco-friendly technologies in the food business and is consistent with sustainable food production methods by encouraging the value-adding of agricultural byproducts.

REFERENCES

AOAC International (2000). *Official Methods of Analysis*, 17th ed.; AOAC International: Rockville, Maryland.

Dag, D., Kilercioglu, M., & Oztop, M.H. (2017). Physical and chemical characteristics of encapsulated goldenberry (*Physalis peruviana* L.) juice powder. *Lebenson. Wiss. Technol*., 83, 86–89.

Demirkol, M.; Tarakci, Z. Effect of Grape (*Vitis labrusca* L.) Pomace Dried by Different Methods on Physicochemical, Microbiological and Bioactive Properties of Yoghurt. *Lebenson. Wiss. Technol.* 2018, *97*, 770–777.

Dimitrellou, D., Kandylis, P., & Koutinas, A.A. (2020). Yogurt production using immobilized *Lactobacillus casei* cells with prebiotics. *Food and Bioproducts Processing,* 124, 418–425.

Gavril (Rațu), R.N., Cârlescu, P.M., Veleșcu, I.D., Arsenoaia, V.N., Stoica, F., Stănciuc, N., Aprodu, I., Constantin, O.E., & Râpeanu, G. (2024). The development of value-added yogurt based on pumpkin peel powder as a bioactive powder. *Journal of Agriculture and Food Research*, *16*(101098), 101098. https://doi.org/10.1016/j.jafr.2024.101098

ISO 13299:2016. *Sensory Analysis, Methodology - General Guidance for Establishing a Sensory Profile*. ISO: Geneva, Switzerland, 2016.

Kowaleski, J., & Battestin, V. (2020). Development of probiotic yogurt with addition of fruit preparations: Physicochemical, microbiological and sensory analyses. *Journal of Food Processing and Preservation, 44*(2), e14316.

Lazăr, M.A., & Catană, M. (2020). Valorization of aronia melanocarpa pomace: Perspectives on bioactive compounds and potential applications. *Scientific Bulletin. Series F. Biotechnologies,* 24, 14–21.

Leyva Daniel, D.E.; Huerta, B.E.; Vizcarra Mendoza, M.G.; Sosa, I.A. Effect of Drying Conditions on the Retention of Phenolic Compounds, Anthocyanins and Antioxidant Activity of Roselle Hibiscus. *Int. J. Food Sci. Technol.* 2013, *48*, 2283–2291.

Lipșa, F. D., Stoica, F., Rațu, R.N., Veleșcu, I.D., Cârlescu, P.M., Motrescu, I., Usturoi, M.G., & Râpeanu, G. (2024a). Red Onion peel powder as a functional ingredient for manufacturing ricotta cheese. *Foods*, *13*(2). https://doi.org/10.3390/foods13020182

Lipsa, F. D., Ulea, E., Gafencu, A.-M., Florea, A.-M., Ratu, R. N., Stoica, F., Motrescu, I., & Râpeanu, G. (2024b). Pumpkin pomace powder as a bioactive powder ingredient for whey cheese production. pumpkin pomace powder as a bioactive powder ingredient for whey cheese production. *Appl. Sci.*, 14, 9624. https://doi.org/10.3390/

Ozdemir, N., & Ozkan, M.M. (2020). *Use of berries in dairy products*. In: A. M. Grumezescu & A. M. Holban (Eds.), Handbook of Food Bioengineering: Volume 14. Berries: Properties, Consumption and Nutrition. London, UK: Academic Press Publishing House, 367–396.

Peng, Y., Zhang, Y., & Sun, Y. (2022). Antioxidant and anti-inflammatory activities of anthocyanins from black chokeberry (*Aronia melanocarpa*) and their applications in yogurt. *Food Chemistry,* 366, 130609.

Plessas, S., Mantzourani, I., Bekatorou, A., & Alexopoulos, A. (2024). Development of a novel functional yogurt supplemented with sea buckthorn juice. *Journal of Food Science and Technology*, 61, 1234–1242.

Postolache, A. N., Veleșcu, I. D., Stoica, F., Crivei, I. C., Arsenoaia, V. N., Usturoi, M. G., Constantinescu, C. G., Lipșa, F. D., Frunză, G., Simeanu, D., & Rațu, R. N. (2023). A Clean-Label Formulation of Fortified Yogurt Based on Rhododendron Flower Powder as a Functional Ingredient. *Foods*, *12*(23), 4365. https://doi.org/10.3390/foods12234365

Raikos, V., McDonagh, A., Ranawana, V., & Duthie, G. (2018). Processing of novel functional foods containing anthocyanins, isothiocyanates and omega-3 fatty acids: Effects on quality characteristics and bioactivity. *Food Research International,* 107, 592–602.

Rincón-León, F. (2003). *Functional foods*. In B. Caballero, L. Trugo, & P. Finglas (Eds.), Encyclopedia of Food Science and Nutrition (2nd ed., pp. 2827–2832). Baltimore, USA: Academic Press Publishing House.