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# Production and Consumer Acceptance of Millet Beverages

*Patrycja Cichońska and Małgorzata Ziarno*

## Abstract

The use of millet for the production of plant-based beverages has beneficial effects because it is healthy and gluten-free. In its raw form, millet is rich in dietary fiber and polyphenols. Millet beverages are characterized by relatively low popularity among the consumers of plant beverages. This is mainly due to the drawbacks, namely the presence of plant flavors and “millet” smell. Constant market growth requires new products to be developed in order to meet the consumers’ expectations. The acceptance of millet beverages significantly increases when these are offered in various flavors. Furthermore, the addition of apple or banana puree to millet recipes can increase their desirability. Stabilization of millet beverages is important as they have the tendency to delaminate. This can be overcome by the use of natural stabilizers such as pectin and agar-agar which seems to be an effective option for these products.

**Keywords:** millet, plant-based beverages, recipe, consumer preferences, milk analogues

## 1. Introduction

Plant-based beverages are a group of products that are continuously gaining significant interest in the food market every year. These products are becoming popular for many reasons. They are mostly used as a vegan substitute for cow’s milk by consumers who restrict or exclude animal products in their diets. This is due to the increasing awareness of the society about the impact of intensive animal husbandry on the climate, as well as the health benefits of using plant-based diets. In addition, beverages prepared from plants are consumed by people who have food allergies and intolerances to specific milk components. They also add great variety to the daily diet.

One of the plant beverages less appreciated among consumers is the millet beverage. Millet is a cereal that has a similar nutritional value as the most popular crops such as wheat and rye. It is highly resistant to high temperatures, drought, and pest activities. Millet products are gluten-free and hence suitable for consumption by people suffering from gluten allergy or intolerance.

Millet is rich in health-promoting ingredients, such as fiber, polyphenols, minerals (including copper, phosphorus, iron), and B vitamins. Consumption of this product can have a positive effect on human health. Millet beverages are yet to become popular among consumers because of their low sensory acceptability. Constant growth of the assortment of plant-based beverages and their increased availability has led to a need to develop new products and improve the existing ones to meet consumers’ needs and expectations.

2. Millet beverage and its consumer acceptance

2.1 Characteristics of millet and its products

Millet (*Panicum* L.) is a plant belonging to a family of grasses that consists of several species of annual plants and perennials. It is one of the oldest cereal plants, originating from the regions of India and Central Asia. The most cultivated millet variety is common millet (*Panicum miliaceum* L.). Millet crops have been known and used probably as early as 7000 or 6000 BC, and are therefore considered as one of the earliest cultivated grain grasses. Since that time, their advantages such as resistance to drought and a relatively short period of maturation have been known, despite the high cultivation of their competitors, wheat and barley. Originally grown in northern China or the Caucasus, millets have spread in all directions and have even reached Europe. Millet is the major food for several people living in hot and dry areas around the world. It is mainly grown in marginal agricultural areas where there are low yields of major crops such as wheat and maize due to poor rainfall. In addition, millet is an important source of carbohydrate and protein for millions of people living in Africa. It is the sixth most cultivated cereal in terms of global agricultural production. The largest producers of millet are India, Nigeria, Niger, and China. Furthermore, millet is resistant to pests and has a short cultivation period compared to major cereals [1, 2].

Owing to its technological and health benefits, millet grains are gaining increasing interest among food technologists and nutritionists every year. Millet-based dishes, beverages, and snacks are known all over the world; however, the grain still dominates only in African countries. Millet has a high nutritional value, which is comparable to the macronutrient content in the seeds of major cereals such as wheat, maize, or rice. **Table 1** compares the nutritional values of different types of cereal grains. These values vary depending on the cereal variety. Millet proteins are a good source of essential amino acids, except for lysine and threonine; however, they are relatively rich in methionine [1–3].

The distribution of macronutrients in millet is similar to that in major cereals; therefore, millet is recognized as a suitable raw material for use in the industrial production of snacks, dietary foods, or baby food. Millet grains require proper processing before consumption. The most popular methods used for its processing are hulling, grinding, flaking, polishing, fermentation, and soaking. These methods improve the nutritional and sensory properties of millet, which includes an increase in the bioavailability of micronutrients and a decrease in the content of antinutritional substances, such as phytic acid. **Table 2** shows a comparison of the average

Type of cereal	Carbohydrates [g/100 g]		Protein [g/100 g]	Fat [g/100 g]
	Starch and sugars	Roughage		
Wheat	60.0–75.0	2.0–3.0	10.0–25.0	2.0–2.6
Rye	65.0–73.2	1.6–2.7	7.2–16.0	1.5–2.3
Barley	68.0–78.0	4.5–7.2	10.5–16.3	1.9–2.6
Oat	31.1–51.0	7.7–19.2	9.0–19.0	3.1–6.6
Maize	68.0–78.0	2.0–3.0	9.0–13.0	4.0–6.0
Millet	58.0–82.0	3.2–11.4	9.8–17.2	1.9–4.8
Rice	65.0–80.0	7.8–12.5	7.0–10.8	1.2–2.5

**Table 1.**  
Comparison of the nutritional value of cereal grains [2, 3].

Type of product	Carbohydrates [g/100 g]		Protein [g/100 g]	Fat [g/100 g]
	Starch and sugars	Roughage		
Millet	70.0	7.3	13.5	3.3
Millet flour	78.7	5.9	12.1	3.6
Millet flakes	80.5	3.8	8.1	3.2
Millet groats	71.6	3.2	11.3	2.9

**Table 2.**  
*Comparison of the average nutritional value of millet and its products [3, 4].*

nutritional value of millet and its products. However, industrial processing is not effective, which often negatively affects the properties of this cereal (e.g. reduction in the nutrient content of the product compared to its raw material) [2].

One of the millet processing methods is hulling. The millet grains are small in size compared to other cereals; therefore, to facilitate hulling, millet is first subjected to a hydrothermal treatment. This treatment contributes to the hardening of its endosperm, the inner tissue of the seed containing nutrient reserves. Shelled millet can be cooked to obtain a soft and edible structure in a short time. However, hulling reduces some of the nutrients in the product, such as dietary fiber, minerals, and polyphenols [1, 2].

In order to obtain millet flour, whole or previously dehulled millet grains are subjected to a milling process. Earlier dehulling removes the bran, which simultaneously reduces the amount of fiber, minerals, and antioxidants in the flour, resulting in an overall reduction in the nutritional value of the product. The use of whole grains to produce flour is therefore more beneficial from a health perspective [2].

Millet flakes are another product obtained by processing. First, millet grains are moistened and directed to the evaporator, where they are subjected to steam under pressure for several minutes. After evaporation, the grains are left to mature and then directed to the roller mill. The crusher reduces the grains to thin flakes with certain moisture content (usually 17–18%). The obtained flakes are dried on a belt dryer at a temperature of approximately 50 degrees Celsius. The dried flakes are then cooled down and sorted properly [5].

To obtain groats from millet, the tegument is removed from the grain and then the hulled grains are polished. Millet groats are known not only for their sensory properties and wide range of use but also for their nutritional value. Groats are an excellent source of energy (starch makes up 65% of the product's weight), plant proteins, magnesium, zinc, and B vitamins (mainly thiamine and riboflavin) [5, 6].

Fermentation is widely used in parts of Africa, mainly because of the low popularity of the other methods of food preservation. This process not only extends the shelf life of a product but also improves its nutritional value and increases the range of products available. Fermented foods are consumed all over the world for their health benefits, but unfortunately fermented millet products are not popular in Europe. Such foods are obtained by the colonization of plants by specific bacterial microflora, whose enzymes (including amylases, proteases, lipases) hydrolyze carbohydrates, proteins, and fats to nontoxic flavors and fragrances. Fermentation improves the sensory properties of a product and enriches it with beneficial microorganisms present in the gastrointestinal tract as well as with bioactive substances produced by these microorganisms. In addition, fermentation reduces the antinutritional substances in the product, such as phytates or protease inhibitors. Consequently, the contents of lysine, tryptophan, and vitamin B2 and the digestibility of the protein are increased. The increase in protein digestibility is due to the degradation of tannins and phytic acid by the enzymes produced by

microorganisms during fermentation. An example of a fermented millet product is Saudi Arabian fermented bread known as lahoh. Although fermentation is a very effective method of millet processing, its use on a commercial scale is limited as this technology has so far been used only in home and laboratory conditions. Industrial use of this millet processing technology requires adapting the equipment and defining appropriate process conditions [2, 7].

In addition to the previously described millet processing methods, the grains can be prepared for consumption just by soaking it in water and subjecting it to thermal treatment. Soaking leads to a reduction in the content of antinutritive compounds, thereby increasing the bioavailability of the minerals present in the millet grains, such as iron and zinc [2].

Millet is a gluten-free cereal, and thus, millet-based products are ideal for consumers suffering from celiac disease or gluten intolerance. However, it is also a limiting factor from the technological perspective. Gluten is a plant protein that facilitates cereal products to absorb water and exhibit consistency, stickiness, and elasticity. Therefore, the lack of this protein in millet decreases its application in the baking industry, where it is usually combined with other cereals such as wheat as a result. However, millet can be used on a large scale for the production of plant-based beverages or breakfast cereals and groats [2, 8].

## **2.2 Characteristics and technology of millet beverage production**

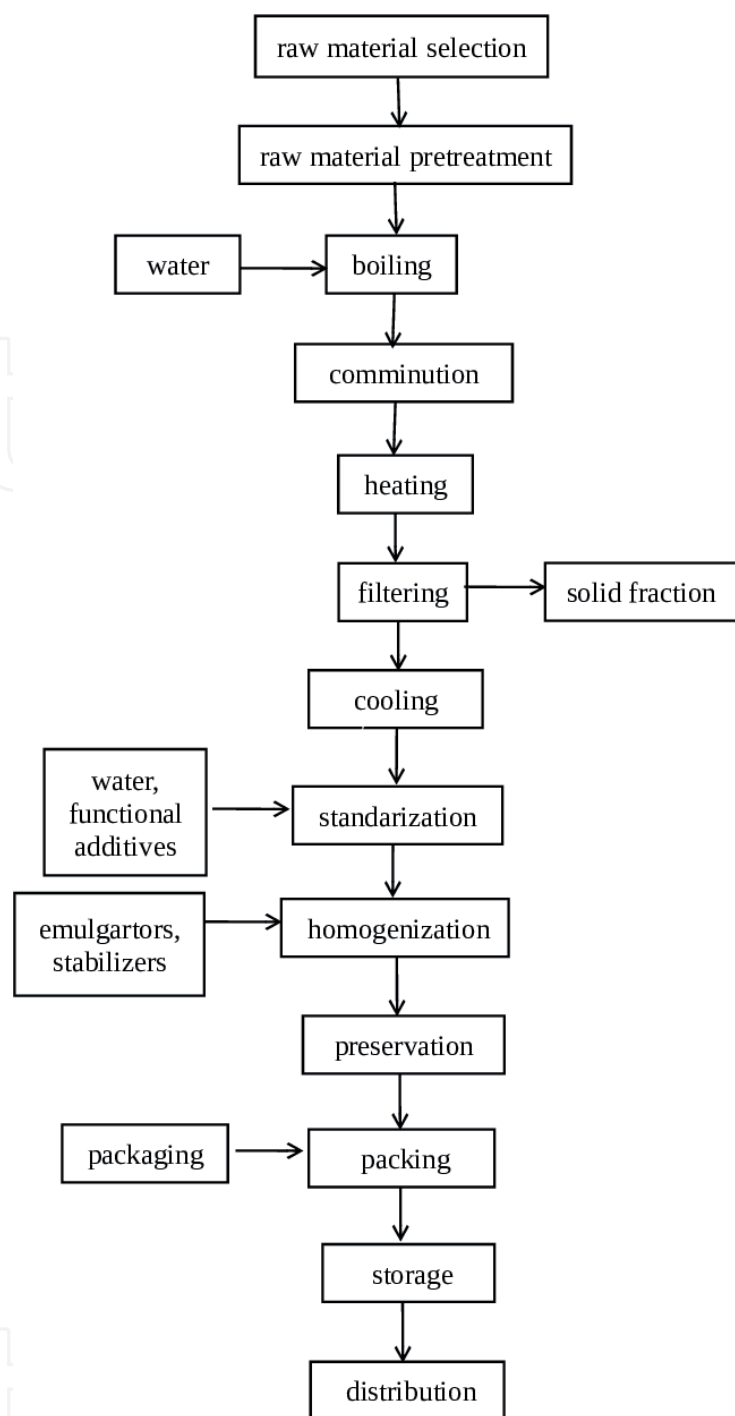
Millet beverages are consumed in the largest quantities in traditional forms such as fermented products. The fermentation process increases the nutritional value of the beverage, as well as ensuring its microbiological safety, without the need for additional preservatives. These types of products are a significant part of the diet mainly in India and African countries because they are identified as highly nutritious and safe food. For example, Jandh is one of the fermented millet beverages. It is a type of beer obtained by fermentation using lactic acid bacteria, yeast, and mold [9, 10].

The production of millet beverage without the fermentation process involves the procedures used in the production of most types of plant beverages. It also includes necessary elements based on the characteristics of the raw material. The stages involved in the production of millet beverage are shown in **Figure 1**. The millet beverage is usually obtained from whole millet grains or groats. When whole grains are used, they are properly prepared by soaking for a minimum period of 12 hours, followed by sprouting and drying. When using groats, the raw material is rinsed thoroughly to eliminate the bitter aftertaste [9, 11, 12].

The properly prepared raw material should be boiled until it reaches a thin consistency. After pretreatment, wet grinding is carried out. Soaking and water extraction allow preparing the raw material for further processing stages and facilitate the release of nutrients. Exposure to water leads to the inactivation of some inhibitors and a reduction in the amount of phytic acid, which consequently increases the absorption and bioavailability of nutrients. The obtained fluid is additionally heated to induce starch thermohydrolysis. At this stage, enzymes are also added to induce hydrolysis of starch. An example of an enzyme used is alpha-amylase, which hydrolyzes the  $\alpha$ -1,4-glycosidic linkage of amylose and amylopectin in starch, resulting in shorter-chain compounds, mainly in the form of dextrans. The use of proteolytic enzymes increases protein digestibility and extraction efficiency, as well as improving the stability of the suspension [9, 12, 13].

The next step in the production of millet beverage is the separation of the solid fraction from the liquid fraction by filtration or centrifugation of the obtained





**Figure 1.**  
Stages in the production of millet beverage [author's own study based on 9–11, 19].

suspension. As a result of the previous stages, the base of a plant beverage is obtained. The obtained base is subjected to the standardization process to obtain a product with the previously assumed composition. Standardization involves the addition of water, vegetable oils, vitamins, and minerals, as well as sweeteners, flavors, salts, and stabilizers. Vitamins and minerals are added to increase the nutritional value of the beverage and make it more similar to cow's milk. The fortifying substances selected for the beverage are required to be highly bioavailable and stable, and not cause excessive changes in the quality of the final product [9, 14, 15].

Millet beverages are characterized by low suspension stability due to the presence of solid particles, including protein, starch, fiber, and other residues of plant

material. These particles have a higher density compared to water, and hence settle at the bottom of the beverage, making the product unstable. In order to increase the stability of millet beverages, homogenization process is carried out, which involves simultaneous grinding and mixing of the particles of the dispersed phase, while forcing the heterogeneous liquid system under high pressure (15–25 MPa) through the homogenizing gap. This operation is done to reduce the diameter and uniformity of the shape of the fat particles contained in the product. As a result, the obtained product is characterized by increased creaminess and homogeneity compared to nonhomogenized products. Homogenization is usually supported by the use of stabilizers, thickeners, and emulsifiers (e.g. cellulose, tapioca, carrageenan, pectin, locust bean gum, or lecithin), which increases the viscosity of the continuous phase, resulting in a uniform structure of the product [9, 15].

In order to ensure microbiological safety and extend the shelf life of plant beverages, thermal preservation methods are used, which mainly include pasteurization and ultrahigh temperature (UHT) treatment. Pasteurization is carried out at a temperature below 100°C, which results in a product with a shelf life of about 1 week at refrigerated temperatures. Such treatment destroys pathogenic microorganisms and inactivates the vegetative forms of other microorganisms. In UHT treatment, the product is heated in flow to 135–150°C for a few seconds to obtain a commercially sterile product. This process destroys the bacterial microflora, while maintaining the taste and aroma of the product. The obtained microbiologically safe product is poured into unit packages, stored, and finally distributed [9, 15].

### **2.3 Consumer acceptance of millet beverage in different forms**

Consumers' acceptance of food products is influenced by many factors, including the characteristics of the offered product, consumer characteristics, and social conditions. Features of a food product such as its price, convenience, taste, general appearance, and health-promoting properties play an important role in its acceptance by consumers. Furthermore, consumer characteristics, such as the approach to innovation, preferences in relation to specific food groups, or nutritional neophobia determine the acceptance of food to a large extent. Food preferences vary among consumers of different age groups, in terms of knowledge about food, views on the health benefits of particular food groups, and attitudes toward food. Consumer acceptance is also influenced by social conditions, such as the country's economy, political conditions, or generally accepted social norms. Cultural factors and the origin of consumers are of great importance in the acceptance of a food product. Another important factor is the general public confidence in the food industry, as well as the existing differences in trust among consumers with regard to traditional and innovative food [16–18].

The consumer acceptance of millet beverage was assessed through a sensory analysis of the beverages produced in various types. The base of the millet beverage was obtained by combining 100 g of millet with 1000 g of tap water. The dry millet was first rinsed with hot water to eliminate the bitter aftertaste, and then added into boiling water and cooked covered for 40 minutes. After the set time, the obtained groats were combined with water, baled into a smooth slurry, and heated again for 5 minutes. The prepared suspension was sieved to obtain 1000 g of base millet beverage and 20 g of decoction. The base millet beverage was characterized by a high density, which was then subjected to two dilutions to prepare natural millet beverages: 1:2 (1 part base millet beverage was combined with 2 parts water) and 1:3 (1 part base millet beverage was combined with 3 parts water). Then, flavored millet beverages were prepared by combining with fruit

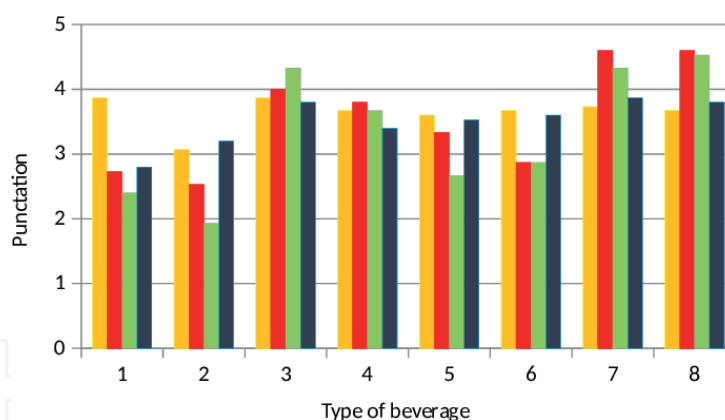
purees (apple and banana), apple juice, and banana nectar. Thus, eight versions of millet beverages in three types were used as research material:

- millet beverage in a dilution of 1:2,
- millet beverage in a dilution of 1:3,
- base millet beverage in combination with apple juice,
- base millet beverage in combination with banana nectar,
- millet beverage in a 1:2 dilution in combination with apple puree,
- millet beverage in a 1:3 dilution in combination with apple puree,
- millet beverage in a 1:2 dilution in combination with banana puree,
- millet beverage in a 1:3 dilution in combination with banana puree.

The sensory analysis of the obtained millet beverages was conducted using an original questionnaire prepared for sensory evaluation. The evaluation was performed by a group of 15 students of Dietetics, Faculty of Human Nutrition, Warsaw University of Life Sciences (SGGW—WULS), who had previously declared their will to consume plant-based beverages. The beverages were prepared 4 days in advance and were cooled in a refrigerator at 8 degrees Celsius until evaluation. The chilled beverages were served as 30 ml samples in coded disposable cups with a volume of 200 cm<sup>3</sup>, in a random order for sensory evaluation. The Statistica 13.1 program was used for statistical analysis of the results. The statistical methods used were analysis of variance—simple ANOVA sections and post hoc analysis—LSD test (last significant differences) [19].

During the sensory evaluation of the tested millet beverages of various types, their taste, smell, color, and consistency were tested. Each of the features was assessed on a 5-point scale, where rating 5 meant that the beverage was very favorable whereas 1 meant that the beverage was very unfavorable. The millet beverage in combination with apple juice (average rating 4.33), millet beverage in a dilution of 1:2 in combination with banana puree (average rating 4.53), and millet beverage in a dilution of 1:3 in combination with banana puree (average rating 4.33) were rated the most favorable in terms of taste. The natural millet beverage in a dilution of 1:2 was rated the least favorable in terms of taste. In terms of color, all the tested beverages were rated at a similar level, and the average ratings were between 3 and 4. Millet beverages in both dilutions in combination with banana puree were rated as the most favorable flavored beverages (average rating 4.60). The millet beverages in the natural form in the dilutions of 1:2 (average rating 2.53) and 1:3 (average rating 2.73) were rated as the least favorable in terms of aroma. The millet beverage in combination with apple juice (average rating of 3.80), the millet beverage in a dilution of 1:2 in combination with banana puree (average rating of 3.80), and the millet beverage in a dilution of 1:3 in combination with banana puree (average rating 3.87) were rated as the most favorable in terms of consistency. The results of the analysis of variance for the mean values given for the sensory traits of the assessed millet beverages of different types are presented as a sensory profile graph in **Figure 2** [19].





**Figure 2.**

Sensory profiles of the evaluated millet beverages of different types [19]. Legend: ■ Color. ■ Smell. ■ Taste. ■ Consistency. 1 - millet beverage in a dilution of 1:2, 2 - millet beverage in a dilution of 1:3, 3 - base millet beverage in combination with apple juice, 4 - base millet beverage in combination with banana nectar, 5 - millet beverage in a 1:2 dilution in combination with apple puree, 6 - millet beverage in a 1:3 dilution in combination with apple puree, 7 - millet beverage in a 1:2 dilution in combination with banana puree, 8 - millet beverage in a 1:3 dilution in combination with banana puree.

The LSD test was used to compare the results obtained from the sensory evaluation of the tested millet beverages in pairs and to evaluate the statistical significance of the calculated differences. The tested pairs were as follows:

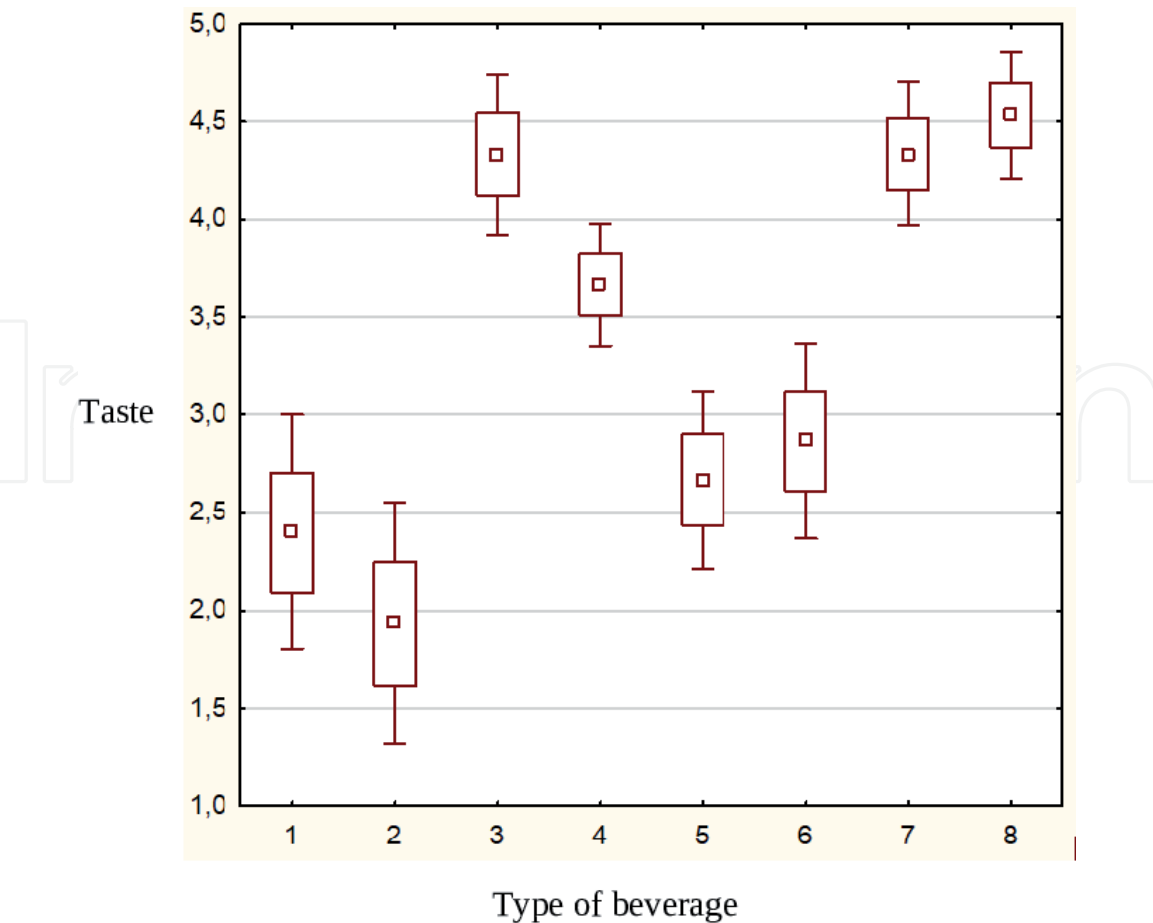
- natural millet beverage in a 1:2 dilution and natural millet beverage in a 1:3 dilution,
- millet beverage in combination with apple juice and millet beverage in combination with banana nectar,
- millet beverage in a 1:2 dilution with apple puree and millet beverage in a 1:3 dilution with apple puree, and
- millet beverage in a 1:2 dilution with banana puree and millet beverage in a 1:3 dilution with banana puree.

In terms of taste, no significant differences were found between natural millet beverages in both dilutions, millet beverages in combination with apple puree in both dilutions, and millet beverages in combination with banana puree in both dilutions. The millet beverage in combination with apple juice was assessed to be significantly better than the millet beverage in combination with banana nectar. The results of the LSD test for the trait “taste” of the evaluated millet beverages are presented in **Figure 3** [19].

In terms of color, significant differences were found only in the case of natural millet beverages. The natural millet beverage in a 1:3 dilution was assessed to be significantly better than the natural millet beverage in a 1:2 dilution. No statistically significant differences were found between the remaining pairs of millet beverages. The results of the LSD test for the trait “color” of the assessed millet beverages are presented in **Figure 4** [19].

In terms of smell, no statistically significant differences were found between the compared pairs of beverages. The results of the LSD test for the trait “smell” of the assessed millet beverages are presented in **Figure 5** [19].

In terms of consistency, no statistically significant differences were found between the compared pairs of beverages. The results of the LSD test for the trait “consistency” of the evaluated millet beverages are presented in **Figure 6** [19].



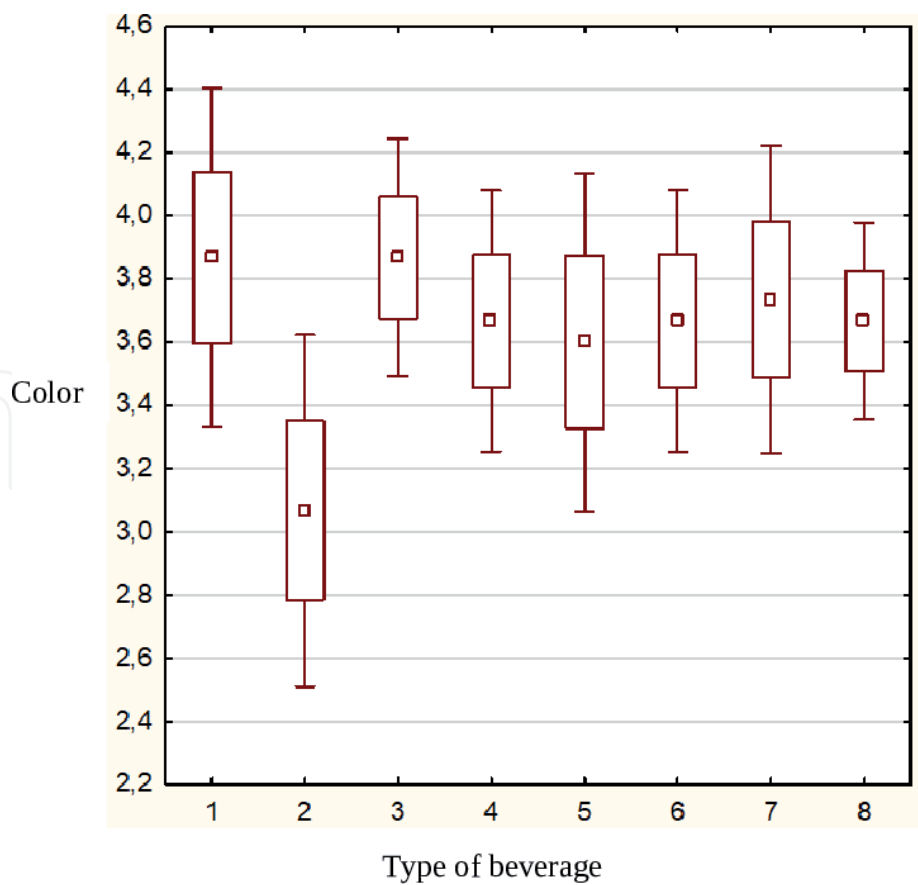
**Figure 3.**  
*Categorized box-whisker chart for trait TASTE of the rated millet beverages [19]. The legend is the same as for Figure 2.*

In the conducted research, taste, smell, color, and consistency were considered as some of the main characteristics that guide consumers in the purchase of food products [20].

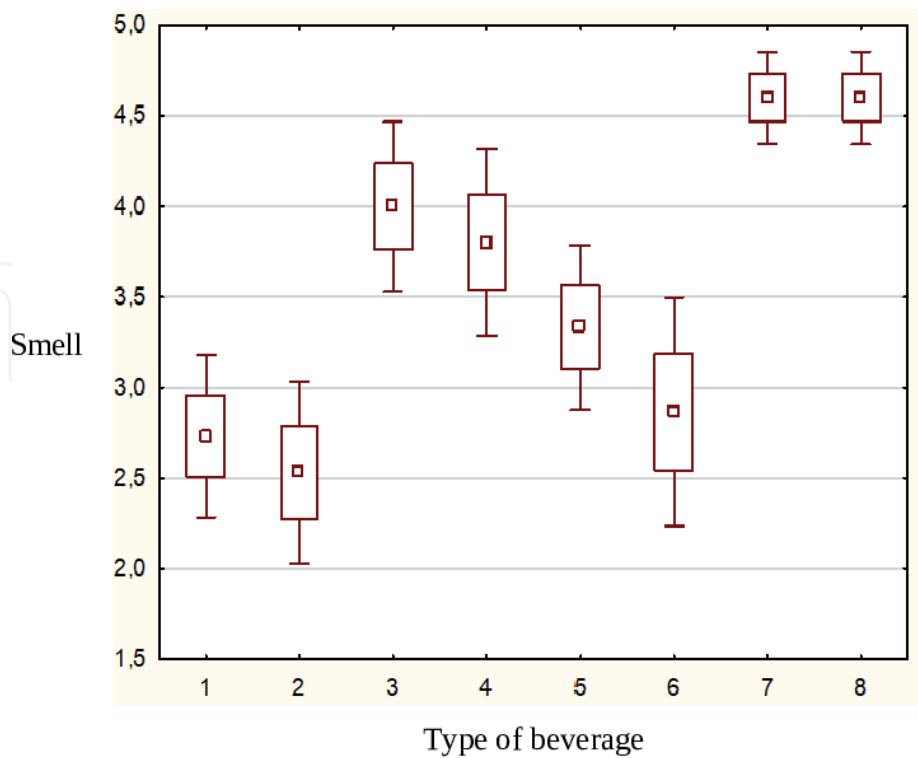
According to people who performed the sensory evaluation, the millet beverages with apple and banana flavors were the best in terms of taste. Banana nectars and purees are characterized by a high intensity of taste and sweetness, which could have influenced the sensory assessors to positively evaluate the beverages containing them. The evaluators rated the natural millet beverage in a dilution of 1:2 as the poorest in terms of taste. Such an assessment could have resulted from the plant aftertaste of the beverages in its natural form, which may not be accepted by all consumers, and also from its high turbidity caused by low dilution [19].

The color ratings of all the tested millet beverages remained at a similar level. Each type of beverage had a specific color, which may have prompted the evaluators to give similar ratings. The only significant difference in terms of color ratings was found between the natural millet beverages. The natural millet beverage in a 1:3 dilution was rated better than that in a 1:2 dilution. Higher dilution gave the beverage a less “milky” color, which is more similar to the color of plant-based beverages available on the market and could be the reason for the higher ratings obtained by the high-diluted natural millet beverage [19].

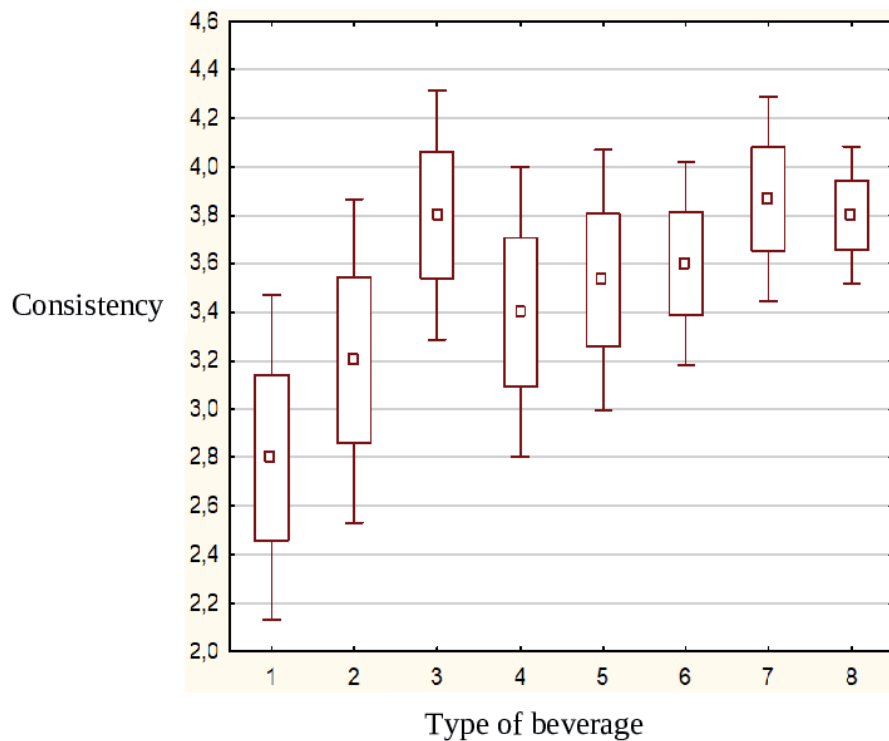
The smell of the natural millet beverage turned out to be the least favorable to the evaluators and was rated the lowest. The banana puree masked the “millet” smell to the greatest extent, which, when combined with the millet beverage, gave it a specific smell. The beverages in combination with banana purees, in both dilutions, therefore turned out to be the most advantageous in terms of aroma for the evaluators and hence were rated the highest [19].



**Figure 4.**  
Categorized box-whisker chart for trait COLOR of the rated millet beverages [19]. The legend is the same as for Figure 2.



**Figure 5.**  
Categorized box-whisker chart for trait SMELL of the rated millet beverages [19]. The legend is the same as for Figure 2.



**Figure 6.**  
 Categorized box-whisker chart for trait CONSISTENCY of the rated millet beverages [19]. The legend is the same as for Figure 2.

The most favorable results in terms of consistency were observed for the millet beverage in combination with apple juice and the millet beverage in combination with banana purees, in both dilutions. Millet beverage in combination with apple juice and millet beverage in a dilution of 1:3 in combination with banana puree showed a similar consistency, specific to refreshing beverages. High ratings given for these types of beverages indicate the consumers' interest in such alternatives available on the market. Millet beverage in a 1:2 dilution in combination with a banana puree with a smoothie consistency was also given high ratings [19].

### 3. Conclusions

Owing to the increase in the popularity of the plant-based diet and thus increasing interest in plant-based beverages, there is a need to develop new products in this category and improve the existing ones.

Millet and millet products are characterized by high nutritional value and technological suitability and can therefore be included in the daily diet.

The structure of millet beverages is suitable for their use in the form of both refreshing beverages (with more water) and smoothies (with less water).

Natural millet beverages have low consumer acceptance. However, the addition of fruit juices and purees during their production can contribute to increasing their sensory attractiveness.

### Conflict of interest

Authors have declared that they do not have any conflict of interest for publishing this research.

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