Plant-based milk Developed from Soy (*Glycine max*) Milk and Foxtail Millet (*Setaria italica*)

Dzul Fadly¹, Wiwi Ulfairah Sutarno², Yuges Saputri Muttalib³, Masturi Muhajir⁴, Fatimah Fitriani Mujahidah⁴

¹Department of Food Technology, Tanjungpura University, Pontianak, Indonesia  
²Department of Nutrition Science, Esa Unggul University, Jakarta Barat, Indonesia  
³Department of Animal Husbandry, Hasanuddin University, Makassar, Indonesia  
⁴Study Program of Nutrition, Universitas Megarezky, Makassar, Indonesia

Email: dzul.fadly@faperta.untan.ac.id

**Abstract:** The presence of lactose and casein content can exacerbate clinical symptoms in people with autism and lactose intolerance. Apart from casein, a low gluten diet can be given to people with autism and celiac disease. Thus, not everyone able to digest and consume dairy milk well. This study aimed to develop plant-based milk products based on soybean milk with the addition of foxtail millet. There were four beverage formulations, F0 (100% soy milk, 0% millet), F1 (90% soy milk, 10% millet), F2 (80% soy milk, 20% millet), and F3 (70% soy milk, 30% millet). A total of 25 semi-trained panelists were involved in this study. Plant-based milk of soy milk with the addition of 10% millet tended to have better hedonic and hedonic quality values than pure soy milk products and soy milk with 20% and 30% millet. The 100% soy milk product (F0) had a viscosity value of 1.07 ± 0.03 and increased along with more millet added, about 1.27 ± 0.02 - 1.58 ± 0.01 cp. Based on the statistical test, the addition of foxtail millet significantly affected the protein, fat, and ash content at α = 0.05. However, it did not significantly affect the carbohydrate, water, and energy content (p> 0.05). In addition, the calcium content might be improved in line with the addition of millet to soy milk. Plant-based milk formulated with soy milk and millet can be an alternative to dairy milk which contains better nutrients than whole soy milk.

1. Introduction

Milk is known as completed food because it is rich in protein, fat, carbohydrates, vitamins, and various minerals essential to support life and maintain health. Naturally, lactose is only found in milk and specific plants in minimal amounts [1]. However, not all individuals can consume animal milk. Animal Milk can harm some individuals with genetic disorders (autism) and physiological disorders (lactose intolerance). Various clinical manifestations occur in the three most commonly affected organ systems, namely the skin, respiratory system, and gastrointestinal tract. Clinical symptoms that can occur in all three systems are urticaria, skin redness, pruritus, atopic dermatitis, nasal congestion, rhinitis, recurrent cough, asthma, vomiting, colic, constipation, diarrhea, bloody bowel movements, and shock duration of onset of symptoms after drinking animal milk. These symptoms can be alleviated by casein and a gluten-free diet [2].

Casein and gluten are proteins that cannot be consumed by people with genetic disorders such as autism. For people with autism who experience indigestion, consuming casein and gluten can exacerbate their clinical symptoms. Although casein and gluten are proteins, casein is a protein derived from cow's milk, and gluten comes from wheat and its processed products such as; wheat, wheat, oats, and barley [3]. It encourages people to choose other alternatives by replacing dairy milk products with plant-based
milk products that can be accepted by individual groups who cannot consume animal milk. One of the non-dairy kinds of milk that are quite popular in the community is soy milk. Soy milk is the processing of soybeans (Glycine max). This plant-based milk has good nutritional value and is suitable for all age groups [4]. Apart from soybeans, other grains are still deficient in use as a food ingredient in Indonesia, one of which is foxtail millet (Setaria italica). Foxtail millet contains carbohydrates ranging from 60-80% and minerals such as calcium, iron, magnesium, phosphorus, zinc, and potassium. Also, most of the foxtail millet does not contain gluten [5]. Thus, this foxtail millet is very suitable for people with genetic disorders (autism) and celiac disease.

This study aimed to develop non-dairy plant-based milk by formulating soy milk foxtail millet.

2. Methods

2.1. Research Design and Materials

It was an experimental research with a completely randomized design (CRD). The main ingredient used in this research was soybean obtained from West Jakarta and foxtail millet obtained from Enrekang, South Sulawesi.

2.2. Product Formulation

Preparing a soy milk formulation with the addition of foxtail millet was divided into four formulations. The four formulations consisted of F0 (as a control formulation), F1, F2, and F3, as seen in Table 1.

Table 1. Formulation of Plant-based Milk Products.

| Ingredients          | F0   | F1   | F2   | F3   |
|----------------------|------|------|------|------|
| **Main ingredients** |      |      |      |      |
| Soy milk (%)         | 100  | 90   | 80   | 70   |
| Jewawut (%)          | 0    | 10   | 20   | 30   |
| **Complementary**    |      |      |      |      |
| Sugar (g)            | 5    | 5    | 5    | 5    |
| Salt (g)             | 2    | 2    | 2    | 2    |
| Stabilizer (g)       | 1    | 1    | 1    | 1    |
| Flavor (g)           | 3    | 3    | 3    | 3    |
| Water (ml)           | 200  | 200  | 200  | 200  |

2.2.1. Soy milk preparation. Soybeans were cleaned and washed. Then, it soaked in clean water for 12 hours and boiled for 15 minutes. The soybeans were peeled, and the husks were removed. The soybeans were added with hot water at a temperature of 90 °C, mashed, and filtered. Added sugar into the soy milk obtained and cooked until boiling. The ratio of soybean and water was 1:5, which produces good quality soy milk and has a slightly sweet taste and slightly thick texture [4].

2.2.2. Foxtail millet paste preparation. The foxtail millet was sorted and washed with clean water. After that, boil the millet with low heat, and the ratio of millet and water was 1:4 [6].

2.2.3. Formulation of Plant-based milk of soy milk with foxtail millet addition. The soy milk and millet paste were weighed, then both were mashed in a food blender. Then, added sugar, stabilizer, and flavor, stirring well until thoroughly mixed.

2.3. Organoleptic Analysis

The panelists needed in this research were 25 semi-trained panelists using VAS (Visual Analog Scale). In the hedonic assessment, sensory acceptance of preference level, the assessment was from very dislike to very like (0 - 10) on the parameters of color, aroma, taste, and texture. In the hedonic quality assessment, the sensory assessment physically on a scale of 0 - 10, on the parameters of color (very dark - bright yellow), aroma (very unpleasant – very fresh), taste (very bitter – very sweet), texture (very liquid – very thick), mouthfeel (very coarse – very fine).
2.4. Chemical analysis
The determination of carbohydrates was done through the By Difference method [7]. While the protein was determined by the Kjeldahl method, the fat was by the Soxhlet method, water was by gravimetric, and ash was by dry ashing method, calcium was analyzed by EDTA titrimetric method, referred to AOAC (2012) [8].

2.5. Viscosity Test
Viscosity was measured using a viscosimeter (Brookfield Digital Viscometer Model DV-E) [9]. The procedure for measuring the viscosity was weighing the 100 ml drink formulation in a 500 ml beaker. Then the spindle number 5 was installed on the viscosimeter, and the speed was set at 50 rpm.

2.6. Data analysis
The data obtained would be processed using Microsoft Excel and SPSS 25.0 software. Data were analyzed statistically through the One Way Anova test and continued with the DMRT (Duncan's Multiple Range) tests at $\alpha = 5\%$.

3. Results and Discussion

3.1. Organoleptic Assessment
The analysis of hedonic value and hedonic quality of plant-based milk products made from soy milk with the foxtail millet addition are presented in Table 2.

| Parameters       | Formulation | F0        | F1        | F2        | F3        | p-value |
|------------------|-------------|-----------|-----------|-----------|-----------|---------|
| Hedonic Color    |             | 6.80 ± 1.81| 7.80 ± 1.51| 7.40 ± 1.73| 7.30 ± 1.00| 0.755   |
| Aroma            |             | 4.80 ± 2.20| 6.96 ± 2.18| 6.14 ± 2.27| 5.12 ± 2.21| 0.003   |
| Taste            |             | 5.40 ± 2.12| 6.78 ± 2.14| 5.70 ± 2.12| 5.01 ± 2.08| 0.026   |
| Texture          |             | 6.41 ± 1.66| 7.16 ± 1.99| 5.81 ± 1.99| 4.70 ± 2.00| 0.001   |
| Hedonic quality  |             | 7.40 ± 1.99| 7.90 ± 1.25| 7.50 ± 1.94| 7.60 ± 1.50| 0.690   |
| Aroma            |             | 5.21 ± 2.69| 6.63 ± 2.57| 5.96 ± 2.45| 4.90 ± 1.78| 0.056   |
| Taste            |             | 4.43 ± 1.98| 5.44 ± 2.18| 4.46 ± 1.99| 4.91 ± 1.66| 0.234   |
| Texture          |             | 3.66 ± 2.17| 4.60 ± 2.44| 5.37 ± 2.35| 6.47 ± 1.78| 0.001   |
| Mouthfeel        |             | 7.60 ± 1.83| 7.10 ± 1.67| 6.40 ± 2.32| 4.80 ± 2.25| 0.001   |

Note: Values are presented as mean ± standard deviation. a, b, c Values followed by different superscript letters on the same line indicate significantly different values ($\alpha = 0.05$).

The addition of foxtail millet to soybean drinks tended to increase preference and the brightness of the drink's color. However, statistically, it did not significantly affect ($p = 0.755$). Likewise, the hedonic quality of the color parameter ($p = 0.690$). Based on the results, the color of milk products with the addition of foxtail millet tended to be bright yellow. The bright yellow color arose due to beta-carotene pigments and flavonoid components such as glycosylvitesin, glycosilorotin, labile alkalis, and ferulic acid [10].

The addition of foxtail millet increased the preference for soy milk and decided the aroma was the distinctive aroma of soybeans. The addition of millet had a statistically significant effect on the hedonic value of aroma ($p = 0.003$). However, it did not significantly affect the hedonic quality of aroma ($p = 0.056$). The product's aroma is influenced by the types of ingredients used and the processes involved in making the drink. In soy milk, there is the oxidation of linolenic acid by the enzyme lipoxygenase, which causes an unpleasant odor.
In this product, the foxtail millet had a significant effect on the hedonic value of the taste parameter (p < 0.05) but not significantly affected its hedonic quality on the same parameter (p > 0.05). The addition of this millet at the F1 level increased the panelists' preference. However, then it decreased when the millet level was increased at F2 and F3. Most of the panelists assessed that the taste of plant-based milk products in the F1 formula was sweet. Like the aroma, the taste of drinks is also influenced by the ingredients and processes used [11]. The lipoxygenase enzyme in soy causes a bitter taste [12]. Whereas in foxtail millet, tannins are responsible for the bitter and bitter taste it causes.

The panelists' preference for plant-based milk increased significantly at the F1 level and decreased at the F2 and F3 levels (P = 0.001). Also, this millet's addition significantly improved the milk's viscosity (P = 0.001). The presence of carbohydrate content in the form of starch, when mixed with water, may cause the starch granules to absorb water to expand and thicken [4].

The addition of foxtail millet affected mouthfeel both hedonic (P = 0.007) and hedonic quality (P = 0.001). The addition of this millet gave a sediment effect on the drink's texture, affecting the products. The smoothness caused by the product greatly plays a role in the stability and mouthfeel. The higher the smoothness of a product, the higher the product stability and the smoother the mouthfeel (lower the coarsely) [13]. Also, the addition of a stabilizer to drink products minimizes the deposition of particles. Based on its function, the stabilizer can provide softness to food products and help form an emulsion from two liquids that are not naturally mixed. The type of stabilizer used in the manufacture of drink products is pectin [14].

3.2. Chemical and Physical Properties

The chemical properties (carbohydrates, protein, fat, water, ash, and energy) and physical property (viscosity) of beverage products made from soy milk with the addition of foxtail millet are presented in Table 3.

| Parameters                  | Formulation | F0          | F1          | F2          | F3          | p-value |
|-----------------------------|-------------|-------------|-------------|-------------|-------------|---------|
| Carbohydrate (%)            |             | 5.17 ± 0.04 | 5.60 ± 2.14 | 6.23 ± 1.90 | 6.38 ± 2.66 | 0.915   |
| Protein (%)                 |             | 1.67 ± 0.02 | 1.43 ± 0.02 | 1.55 ± 0.03 | 1.74 ± 0.03 | 0.001   |
| Fat (%)                     |             | 0.58 ± 0.02 | 0.68 ± 0.01 | 0.89 ± 0.02 | 0.88 ± 0.02 | 0.001   |
| Water (%)                   |             | 92.20 ± 0.01| 91.63 ± 2.14| 90.93 ± 1.83| 90.69 ± 2.60| 0.854   |
| Ash (%)                     |             | 0.38 ± 0.01 | 0.66 ± 0.01 | 0.40 ± 0.01 | 0.31 ± 0.01 | 0.001   |
| Energy (Kcal)               |             | 32 ± 0.11   | 34 ± 8.60   | 39 ± 7.27   | 40 ± 10.31  | 0.710   |
| Viscosity                   |             | 1.07 ± 0.03 | 1.27 ± 0.02 | 1.36 ± 0.03 | 1.58 ± 0.01 | 0.001   |

Note: Values are presented as mean ± standard deviation. a, b, c Values followed by different superscript letters on the same line indicate significantly different values (p ≤ 0.05).

Many carbohydrates are found in plants, both as simple sugars such as hexose and pentose, and in the form of high molecular weight carbohydrates such as starch, pectin, cellulose, and lignin. Carbohydrates are compounds formed from carbon, hydrogen, and oxygen molecules [15,16]. The function of carbohydrates is as the primary energy provider, a regulator of fat metabolism, protein saver, brain and nerve energy supply, glycogen storage, and intestinal peristalsis regulator. Apart from their function in the body's metabolism, carbohydrates responsible for a sweet taste to food due to sugar, a distinctive aroma, and shape, providing color, texture, and softening the food. In formulation F0 to F3, the carbohydrate content tended to increase, but it was not statistically significant (p > 0.005). It shows that the addition of millet at the formulation level in this study did not affect even though it had an increasing trend.

Protein is a type of nutrient that the body needs to replace damaged cells and also for growth. Protein is also a compound in macromolecules present in every organism, with different characteristics [17]. Proteins play a role in growth, formation of structural components, transport and storage of nutrients, enzymes, formation of antibodies, energy sources, and regulating water and acid-base balance. In this study, plant-based soy milk with foxtail millet tended to experience a significant reduction in protein content (p = 0.001). Soybeans contain an average of 35% protein, while millet protein is known to be

---

**Table 3. Chemical and physical properties of soy milk with the addition of foxtail millet.**

| Parameters                  | F0          | F1          | F2          | F3          | p-value |
|-----------------------------|-------------|-------------|-------------|-------------|---------|
| Carbohydrate (%)            | 5.17 ± 0.04 | 5.60 ± 2.14 | 6.23 ± 1.90 | 6.38 ± 2.66 | 0.915   |
| Protein (%)                 | 1.67 ± 0.02 | 1.43 ± 0.02 | 1.55 ± 0.03 | 1.74 ± 0.03 | 0.001   |
| Fat (%)                     | 0.58 ± 0.02 | 0.68 ± 0.01 | 0.89 ± 0.02 | 0.88 ± 0.02 | 0.001   |
| Water (%)                   | 92.20 ± 0.01| 91.63 ± 2.14| 90.93 ± 1.83| 90.69 ± 2.60| 0.854   |
| Ash (%)                     | 0.38 ± 0.01 | 0.66 ± 0.01 | 0.40 ± 0.01 | 0.31 ± 0.01 | 0.001   |
| Energy (Kcal)               | 32 ± 0.11   | 34 ± 8.60   | 39 ± 7.27   | 40 ± 10.31  | 0.710   |
| Viscosity                   | 1.07 ± 0.03 | 1.27 ± 0.02 | 1.36 ± 0.03 | 1.58 ± 0.01 | 0.001   |
worth 9-12%. According to Fuleky (2009), foxtail millet protein has an albumin and globulin protein fraction of 22-28%, prolamin 28-35%, glutelin 28-32% [10]. All types of foxtail millet have limited content of the amino acid lysine.

Fat is one component of multifunctional food that is very important for life. Fat is also a source of energy. The essential components of fat are fatty acids and glycerol obtained from the hydrolysis of fats, oils, and other lipid compounds [18]. In this study, the fat content increased significantly with increased foxtail millet added (P = 0.001). The fat content in soybeans is around 18-20%, and 25% of this amount consists of cholesterol-free unsaturated fatty acids. In addition, soybean fat contains several essential phospholipids, namely lecithin, sepalin, and lipositol. According to Fuleky (2003), the fat content in foxtail millet is generally higher than sorghum (3-6%), as much as 75%, including long-chain unsaturated fatty acids (PUFA), with the most PUFA types being linoleic acid [10].

Water content in food or product ingredients is an essential factor that plays a role in forming the organoleptic properties of these products. The amount of water content in a product affects its texture and taste. Jewawut has a water content that is not too high. Formulation F3 with the lowest moisture content is due to the addition of foxtail millet 30%, which is higher than the addition of formulations F0, F1, and F2. However, this reduction in water content was not statistically significant (p = 0.854). The starch concentration in foxtail millet affects the ability to bind water at the time of gelatinization. Water is bound by starch when gelatinization occurs and will be lost when heating. The more the amount of starch in food, the more water will be bound, and the more water is lost when heating and causing low water content.

Soymilks with the addition of foxtail millet have low ash content. The presence of foxtail millet has a significant effect on ash content (P = 0.001). The ash content shows the crude mineral profile of the food. The polished process of foxtail millet causes the loss of the epidermis rich in mineral components such as Ca, P, Fe, and Zn. It was resulting in a decrease in the ash content of the product. The four product formulations showed no significant difference in the energy content of the products (P = 0.001). The energy content in soy milk was low, but the energy content in foxtail millet has a high energy content. Carbohydrates in foxtail millet range from 60-80%. These millet grains do not contain gluten and contain high energy content, making them very suitable for people with celiac disease [19].

One of the physical properties of these non-dairy milk products is viscosity. The viscosity values of the four products were different and increased significantly (p = 0.001). Milk protein provides physical stability to the emulsion and dissolved particles in food products by affecting the system's viscosity. This property is also influenced by external conditions such as temperature, concentration, pH, ionic strength, and the processing process that has been passed [9]. In addition, the more foxtail millet added to the formulation and the reduced volume of soy milk, the viscosity was getting thicker.

3.3. Calcium Content

![Figure 1. The calcium content of soy milk drinks with the addition of foxtail millet.](image-url)
Calcium is a macromineral that the body needs and is in the form of anionic electrolytes or negatively charged and cations or positively charged. Calcium functions for the formation of bones and teeth and regulate muscle contraction, including heart rate. Calcium also influences the blood clotting process. Good sources of calcium are milk, nuts, bread, fish, and others.

Figure 1 shows an increase in the amount of calcium in line with increased foxtail millet added. However, higher foxtail millet would decrease the amount of calcium, as was F3. According to Fuleky (2009), Foxtail millet also contains anti-nutritional substances, oxalic acid, which bind calcium to form a calcium complex, thereby reducing the availability of calcium [10].

4. Conclusion
The formulation of plant-based milk with whole soy milk and 10% foxtail millet increased the sensory acceptances. Besides, foxtail millet in plant-based milk formulations may improve the chemical and physical properties and the calcium content of soy milk.

References
[1] Hasim M E 2010 Perbandingan susu sapi dengan susu kedelai: tinjauan kandungan dan biokimia absorsbi Semiloka Nas. Prospek Ind. 28 272–8
[2] Siregar S P and Munasir Z 2016 Pentingnya Pencegahan Dini dan Tata laksana Alergi Susu Sapi Sari Pediatr. 7 237–43
[3] Reissmann A, Hauser J, Makulksa-Gertruda E, Tomsa L and Lange K W 2014 Gluten-free and casein-free diets in the treatment of autism Funct. Foods Heal. Dis. 4 349–61
[4] Picaulpy, Talahatu J and Mailoa M 2015 Pengaruh penambahan air pada pengolahan susu kedelai AGRITEKNO J. Teknol. Pertan. 4 8–13
[5] Siregar N S 2014 Karbohidrat J. Ilmu Olahraga 13 38–44
[6] Riyanti F, Rusmarilin H and Nainggolan R 2014 Pengaruh Perbandingan Bubur Tempe Dengan Perbandingan Zat Penstabil Terhadap Mutu Selai J. Ilmu dan Teknol. Pangan 19 80–91
[7] Winarno F G 2004 Kimia Pangan dan Gizi Jakarta (Jakarta: PT Gramedia Pustaka)
[8] AOAC 2012 Official methods of analysis (Association of Official Analytical Chemists Washington, DC)
[9] Fuleky G 2009 Cultivated plants, primarily as food sources (EOLSS Publications)