Effect of addition of sugar and non-dairy creamer on sensory acceptance, physical properties, and antioxidant activity of sorghum-adlay milk

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Abstract. The popularity and demand of alternative beverages made from plants have gained attention over the last year due to health reasons. Cereal plants such as sorghum (*Sorghum bicolor* L.) and adlay (*Coix lacryma-jobi* L.) can be utilized as raw materials for the production of plant-based milk. However, information on the development of sorghum-adlay milk is still limited, especially regarding the ingredients used and their influence on the characteristics of the final product. The aim of this research was to investigate the effect of sugar and non-dairy creamer (NDC) addition on the sensory acceptance, color, physical stability, total soluble solids, pH, and antioxidant activity of sorghum-adlay milk. There were 15 samples formulated with different concentrations of sugar (4-20%) and NDC (0-2%). The results showed that samples with 20% sugar and 2% NDC had the highest sensory acceptance by the panelists. The addition of NDC significantly influenced the color of samples, which increased the L^* value and decreased the a^* and b^* values ($p<0.05$). It also increased the total soluble solids and physical stability of the product ($p<0.05$). A higher concentration of NDC in the product could decrease the antioxidant activity of the alternative milk ($p<0.05$).

1 Introduction

Plant-based milk is becoming increasingly popular among consumers looking for dairy-free and lactose-free alternatives [1]. Various factors, including health concerns, ethical considerations, and environmental sustainability, drive this trend [2]. While plant-based milk may not have the same nutritional profile as animal milk, it can still provide valuable nutrients through the fortification of nutrients [3]. Additionally, plant-based milk can be lower in fat and calories than animal milk, which may appeal to those looking to maintain a healthy weight or reduce their saturated fat intake [4].

Indonesia is the world's fourth most populated country, and as the economy increases, so does the desire for alternative and sustainable food items [5]. Plant-based milk products are becoming more readily available in Indonesia, such as soy milk and almond milk.

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Furthermore, numerous local enterprises are beginning to create and market plant-based milk products such as coconut milk and soy milk. In addition, there are still many local resources that can be used as raw materials for making alternative milk. One of them is sorghum.

Sorghum (*Sorghum bicolor* L.) is one of the most widely cultivated cereal grains in the world and is consumed as a staple food among people in Africa and Southeast Asia [6]. The utilization of these underutilized crops in Indonesia as a staple food is encouraged by the government to decrease the dependency on rice. Sorghum has been previously reported to have high nutritional content and bioactive compounds that are beneficial for human wellness [7, 8]. To popularize the consumption of sorghum, the utilization of sorghum in popular processed foods such as beverages is the main topic of this research. To improve the characteristics of the final product, the incorporation of another plant seed, such as adlay (*Coix lacryma-jobi* L.), was conducted in this research. So far, information on the development of sorghum-based drinks in Indonesia is limited. No commercial sorghum-based beverage has been widely sold on the market. Therefore, this research tried to evaluate the formulation of sorghum and adlay and investigate the sensory acceptance, physical appearance, and antioxidant activity of the sorghum-adlay-based beverage.

2 Material and methods

2.1 Material

Red sorghum and adlay were purchased from Greenara (Jakarta, Indonesia). The chemicals used for analysis were purchased from Merck (Daamstadt, Germany).

2.2 Sample preparation

Sorghum and adlay milk were prepared according to the method previously described with slight modifications [4]. First, the materials were washed three times to remove impurities and soaked in water for 12 hours. Then, the materials were blended with water using a Mitochiba blender at medium speed for 2 minutes with a ratio of 4:1 (400 ml water to 100 ml material). The liquid was filtered using cheesecloth to obtain the extract, which was then boiled at 90 °C for 15 minutes. The resulting milk was hot-filled into a container, cooled, and stored at 4 °C for further analysis. Based on previous research, 80% sorghum and 20% adlay were chosen as the best formulation and then further formulated with sugar (with a concentration range of 4-12%) and non-dairy creamer (with a concentration range of 0-2%). The details of the formula are shown in Table 1.

Table 1. Formulation of sorghum-adlay milk

Formula	Sugar (%)	Non-dairy creamer (%)
1	4	0
2	4	1
3	4	2
4	8	0
5	8	1
6	8	2
7	12	0
8	12	1
9	12	2

10	16	0
11	16	1
12	16	2
13	20	0
14	20	1
15	20	2

2.3 Sensory Evaluation

Sensory analysis was carried out using a hedonic test with a total of 40 untrained panelists. Sensory examination was carried out for all sample formulations to determine the effect of the addition of sugar and non-dairy creamer on the acceptance of sorghum adlay milk. Panelists received approximately 25 ml of each sample in a cup assigned three random numbers. Then the panelists were asked to assess the preference using a 9-point scale (overall, taste, color, aroma, viscosity, and mouthfeel or aftertaste), where 1 was for intensely disliked and 9 was for strongly liked.

2.4 Color analysis

The color evaluation was carried out using the portable colorimeter NH300 (3NH, China) to measure the values of L* (lightness), a* (red and green intensity), and b* (yellow and blue intensity), as well as C (chroma), H (hue), and E (color difference) for each sample. Each sample was measured in triplicate, with three repetitions.

2.5 Physical stability

A physical stability test was carried out by storing the sample at 4 °C for three days, or 72 hours, in a 15 ml falcon tube. Then, the sample was centrifuged to see the number of liquids separated. The volume of the upper phase (supernatant) that was separated was measured and observed daily for 24 hours. Each sample was measured in triplicate, with three repetitions.

2.6 pH and total soluble solids content analyses

Total soluble solids were measured using a Brix refractometer (ATC 0-32%). pH analysis was carried out using the pH meter (EUTECH pH 700). Each sample was measured in triplicate, with three repetitions.

2.7 Antioxidant activity

The analysis of antioxidant activity was conducted using the DPPH method [9]. Each sample was measured in triplicate, with three repetitions.

2.8 Statistical analysis

The analysis of the samples was conducted in triplicate in three independent experiments. The data were calculated as mean ± SD. The data obtained were further analyzed using IBM SPSS 22.0 statistical software. A one-way ANOVA and Duncan's New Multiple Range Test at a confidence interval of 95% ($p<0.05$) were used to observe the significant difference between samples.

3 Result and Discussion

3.1 Sensory acceptance sorghum-adlay milk

There are 15 samples of sorghum-adlay milk formulated with sugar and non-dairy creamer. The liking attributes in the samples were evaluated using a hedonic rating test. The result of hedonic acceptance by panelists is shown in Table 2.

Table 2. Sensory acceptance of sorghum-adlay milk

Formula	Overall	Taste	Color	Odor	Viscosity	Mouthfeel
1	2.3±2.1 ^{a}	5.3 ± 2.1 ^{b}	4.6 ± 1.9 ^{a}	5.0 ± 2.0 ^{a}	4.9 ± 1.8 ^{a}	5.5 ± 2.0 ^{a}
2	2.8 ± 2.1 ^{a}	4.6 ± 1.8 ^{a}	5.5 ± 1.8 ^{bcdef}	5.3 ± 1.6 ^{ab}	5.5 ± 1.9 ^{abcde}	5.4 ± 1.7 ^{a}
3	2.8 ± 1.9 ^{a}	4.4 ± 2.1 ^{a}	5.1 ± 2.4 ^{ab}	4.9 ± 2.0 ^{a}	5.4 ± 2.1 ^{abc}	5.0 ± 2.4 ^{a}
4	2.6 ± 1.8 ^{a}	6.1 ± 1.8 ^{cd}	5.3 ± 1.8 ^{bcd}	5.5 ± 1.8 ^{abc}	5.2 ± 1.7 ^{ab}	6.1 ± 1.9 ^{b}
5	3.7 ± 2.1 ^{b}	5.4 ± 1.7 ^{b}	5.5 ± 1.7 ^{bcde}	5.0 ± 1.8 ^{a}	5.4 ± 1.8 ^{abcd}	5.4 ± 1.7 ^{a}
6	3.9 ± 2.2 ^{b}	5.8 ± 1.6 ^{bc}	6.5 ± 1.7 ^{g}	5.9 ± 1.8 ^{bcd}	6.0 ± 1.7 ^{cdef}	6.2 ± 1.6 ^{b}
7	3.8 ± 2.2 ^{b}	6.6 ± 1.9 ^{de}	5.6 ± 1.8 ^{bcdef}	5.9 ± 1.8 ^{bcd}	5.7 ± 1.8 ^{bcde}	6.2 ± 2.0 ^{b}
8	4.8 ± 2.3 ^{c}	5.5 ± 2.5 ^{bc}	5.2 ± 2.1 ^{bc}	5.0 ± 2.1 ^{a}	5.4 ± 2.2 ^{abc}	5.5 ± 2.4 ^{a}
9	5.1 ± 2.0 ^{cd}	6.5 ± 1.5 ^{de}	6.2 ± 1.6 ^{fg}	5.9 ± 1.7 ^{bcd}	6.1 ± 1.6 ^{ef}	6.6 ± 1.6 ^{bc}
10	4.7 ± 2.1 ^{c}	6.9 ± 1.7 ^{e}	6.0 ± 1.9 ^{defg}	6.1 ± 1.6 ^{cd}	6.0 ± 1.6 ^{cdef}	6.5 ± 1.9 ^{bc}
11	6.3 ± 2.1 ^{ef}	6.6 ± 2.0 ^{de}	6.1 ± 1.8 ^{efg}	6.2 ± 1.8 ^{d}	6.1 ± 1.8 ^{ef}	6.4 ± 2.2 ^{bc}
12	5.7 ± 2.1 ^{de}	7.1 ± 2.0 ^{e}	6.4 ± 1.8 ^{g}	6.5 ± 1.5 ^{d}	6.5 ± 1.5 ^{f}	6.9 ± 1.8 ^{c}
13	6.0 ± 2.0 ^{e}	6.6 ± 2.1 ^{de}	5.9 ± 1.8 ^{cdefg}	5.8 ± 1.9 ^{bcd}	5.8 ± 1.8 ^{bcde}	6.2 ± 2.0 ^{b}
14	6.9 ± 1.9 ^{f}	6.5 ± 2.0 ^{de}	6.0 ± 1.8 ^{efg}	5.9 ± 1.9 ^{bcd}	6.1 ± 1.7 ^{def}	6.4 ± 1.8 ^{bc}
15	8.1 ± 1.1 ^{g}	8.0 ± 1.6 ^{f}	7.5 ± 1.5 ^{h}	7.3 ± 1.5 ^{e}	7.3 ± 1.6 ^{g}	8.0 ± 1.3 ^{d}

The results showed that sample 15 (20% sugar and 2% non-dairy creamer) is the most preferred sample by panelists in terms of overall, taste, color, odor, viscosity, and mouthfeel. Generally, sorghum and adlay contain tannin and phenolic content that contributes to the astringency and bitterness in foods and beverages [10]. The addition of sugar could reduce the astringency and bitterness in samples. The results showed that the higher the concentrations of sugar added to the product, the higher the acceptance score of overall and taste attributes. The addition of non-dairy creamer also contributed to the increase in sample liking. This result could be attributed to the ability of non-dairy creamer to lighten the color of the product and improve the viscosity and mouthfeel.

3.2 Color analysis of sorghum-adlay milk

Color analysis was carried out based on CIE L*a*b* and L*C*H* by calculating each sample's average value, as seen in Table 3. The value of L* (lightness) shows a range of 0 (black) to 100 (white). Values a* and b* are chroma coordinates, where a* (+) indicates red and a* (-) indicates green, while b* (+) indicates yellow and b* (-) values blue. The L*C*H* value consists of three-color components, namely the L* (lightness), C* (color saturation), and H* (hue angle) values.

Table 3. Sensory acceptance of sorghum-adlay milk

Formulation	Color					
	L*	a*	b*	C*	H*	E*
1	-9.31 ± 0.06^{b}	4.68 ± 0.04^{e}	0.41 ± 0.02^{c}	3.97 ± 0.04^{f}	96.34 ± 0.02^{cdef}	54.98 ± 0.06^{f}
2	5.28 ± 0.23^{de}	3.57 ± 0.12^{b}	-0.92 ± 0.23^{ab}	2.39 ± 0.18^{bc}	96.15 ± 0.04^{ab}	40.35 ± 0.23^{cd}
3	11.46 ± 0.05^{g}	3.79 ± 0.02^{c}	-1.04 ± 0.01^{ab}	2.55 ± 0.02^{cd}	96.34 ± 0.01^{cdef}	34.20 ± 0.06^{a}
4	-10.24 ± 0.06^{a}	4.78 ± 0.05^{e}	0.25 ± 0.04^{c}	3.97 ± 0.06^{f}	96.44 ± 0.02^{ef}	55.91 ± 0.06^{g}
5	4.69 ± 0.26^{cd}	4.09 ± 0.19^{d}	0.01 ± 0.27^{c}	3.28 ± 0.29^{e}	96.14 ± 0.04^{a}	40.97 ± 0.27^{de}
6	11.64 ± 0.04^{g}	3.93 ± 0.01^{cd}	-0.96 ± 0.02^{ab}	2.70 ± 0.01^{cd}	96.38 ± 0.01^{def}	34.02± 0.04^{a}
7	-9.35 ± 0.04^{b}	4.69 ± 0.03^{e}	0.21 ± 0.05^{c}	3.87 ± 0.04^{f}	96.40 ± 0.01^{ef}	55.02 ± 0.03^{f}
8	4.07± 0.03^{c}	3.48 ± 0.02^{b}	-1.31 ± 0.03^{bc}	2.19 ± 0.02^{ab}	96.28 ± 0.01^{cd}	41.56 ± 0.03^{e}
9	10.74 ± 0.04^{f}	3.82 ± 0.02^{c}	-0.98 ± 0.02^{ab}	2.59 ± 0.02^{cd}	96.33 ± 0.01^{cdef}	34.91 ± 0.04^{b}
10	-8.89 ± 0.03^{b}	4.68 ± 0.02^{e}	0.35 ± 0.04^{c}	3.93 ± 0.04^{f}	96.36 ± 0.01^{cdef}	54.56 ± 0.03^{f}
11	5.58 ± 0.04^{e}	3.27 ± 0.03^{ab}	-1.40 ± 0.03^{a}	2.07 ± 0.03^{ab}	96.25 ± 0.01^{bc}	40.06 ± 0.04^{c}
12	10.26 ± 0.0^{f}	3.78 ± 0.01^{c}	-1.01 ± 0.00^{ab}	2.55 ± 0.01^{cd}	96.32 ± 0.01^{cde}	35.39 ± 0.02^{b}
13	-9.15 ± 0.21^{b}	4.82 ± 0.05^{e}	0.30 ± 0.15^{c}	4.04 ± 0.08^{f}	96.44 ± 0.05^{f}	54.83 ± 0.20^{f}
14	4.48 ± 0.08^{c}	3.27 ± 0.03^{a}	-1.52 ± 0.03^{a}	1.97 ± 0.03^{a}	96.26 ± 0.03^{bc}	41.15 ± 0.08^{e}
15	11.91 ± 0.08^{g}	3.95 ± 0.02^{cd}	-0.78 ± 0.02^{ab}	2.78 ± 0.02^{d}	96.32 ± 0.01^{cde}	33.76 ± 0.08^{a}

According to the results obtained, the addition of sugar without creamer has no significant effect to the color of sorghum-adlay milk, but the addition of creamer up to two percent could increase L* value, decrease a* and b* value significantly ($p<0.05$). Non-dairy creamer utilization as ingredient in beverage production has been known to improve texture and lighten the color of beverage [11].

3.3 Physical stability of sorghum-adlay milk

Physical stability test aims to measure the water release from the system after storage. Based on the results shown in Figure 1, the addition of sugar more than 4% did not have a significant effect to the physical stability of sorghum-adlay milk. The addition of non-dairy creamer significantly improves the stability of the product ($p<0.05$). Non-dairy creamer has been reported to have emulsifying ability in beverage, preventing the precipitation of solid particles, thus contributing to the stability of product [12].

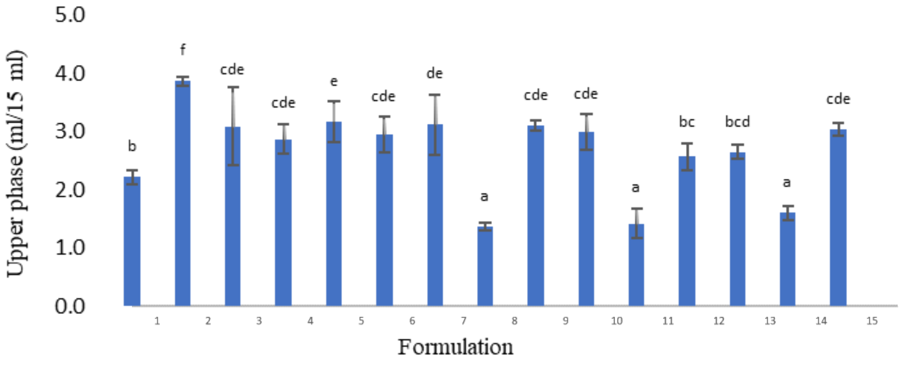

Fig. 1. Upper phase of sorghum-adlay milk with different ratio of sugar and non-dairy creamer

3.4 Total soluble solid and pH of sorghum-adlay milk

Total dissolved solids indicate the percentage of sugar or dissolved solids in a solution. Sugar and creamer significantly affect total dissolved solids but have no significant impact on acidity of product (Table 4).

Table 4. Total soluble solids and acidity of sorghum-adlay milk

Formulation	Total soluble solids	pH
1	1.56 ± 0.06^{a}	7.17 ± 0.010^{bc}
2	3.00 ± 0.08^{c}	7.37 ± 0.004^{c}
3	4.03 ± 0.08^{e}	7.19 ± 0.004^{bc}
4	2.37 ± 0.13^{b}	7.16 ± 0.004^{bc}
5	3.96 ± 0.06^{e}	6.80 ± 0.004^{a}
6	4.99 ± 0.08^{g}	7.18 ± 0.004^{bc}
7	3.48 ± 0.11^{d}	7.09 ± 0.013^{abc}
8	5.00 ± 0.09^{g}	7.01 ± 0.009^{ab}
9	5.99 ± 0.05^{h}	7.17 ± 0.009^{bc}
10	4.50 ± 0.13^{f}	7.09 ± 0.008^{abc}
11	6.00 ± 0.09^{h}	7.05 ± 0.004^{ab}
12	7.04 ± 0.08^{j}	7.13 ± 0.004^{bc}
13	5.02 ± 0.05^{g}	7.12 ± 0.016^{bc}
14	6.53 ± 0.27^{i}	7.04 ± 0.008^{ab}
15	8.22 ± 0.20^{k}	7.21 ± 0.008^{bc}

3.5 Antioxidant activity of sorghum-adlay milk

The antioxidant activity of sorghum-adlay milk was observed using DPPH method. Table 5 showed that addition of sugar did not affect the inhibition activity of antioxidant in the samples. However, non-dairy creamer significantly reduces the antioxidant activity of sorghum-adlay milk ($p<0.05$). The mechanism on how non-dairy creamer decreases antioxidant activity is still unknown. However, previous study revealed that the addition of non-dairy creamer affects the bioavailability of antioxidant in coffee, proved by lower maximum plasma concentrations of antioxidant in blood sample [13]. In regard to the finding, the lower antioxidant activity in higher non-dairy creamer concentration, could be attributed to the bioavailability of antioxidant.

Table 5. Antioxidant activity of sorghum-adlay milk

Formula	Percent Inhibition (%)
1	79.81 ± 0.64
2	84.94 ± 0.37
3	86.22 ± 0.37
4	88.89 ± 0.51
5	88.68 ± 0.37
6	66.99 ± 0.86
7	56.94 ± 0.81
8	49.04 ± 0.37
9	31.20 ± 0.51
10	26.07 ± 0.51
11	47.12 ± 0.85
12	43.91 ± 2.80
13	28.85 ± 1.70
14	15.92 ± 2.36
15	7.05 ± 1.48

4 Conclusion

It can be concluded that the addition of sugar and non-dairy creamer could influence the sensory acceptance, color, total soluble solids, and antioxidant activity of sorghum-adlay milk. Sorghum formulated with 20% sugar and 2% non-dairy creamer showed the highest hedonic acceptance. The addition of non-dairy creamer significantly changes the color, total soluble solids, and physical stability of sorghum-adlay milk. The addition of creamer in sorghum-adlay milk could reduce its inhibitory antioxidant activity.

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