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Sensory and Physical Properties of Jelly Candy Added with Porang (*Amorphophallus oncophyllus*) Macerated with *Strobilanthes crispus* as A Low-Calorie Food Product

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ABSTRACT

Porang (*Amorphophallus oncophyllus, AO*) is a local food source that may be developed to address food security concerns. Diversification in processing should be done to increase its consumption. *Amorphophallus oncophyllus* macerated with *Strobilanthes crispus* (AOSC) was added to jelly candy, which was created as a low-calorie food product with useful antihyperglycemic qualities. This study aimed to evaluate the sensory and physical properties of jelly candy, including color and texture. Jelly candy varied in the concentration of AOSC, namely: 0.2, 0.5, 0.7, and 0.9%. The content of macronutrients was analyzed to prove the calorie value of jelly. The sensory evaluation was carried out using a hedonic scale, while color and texture profiles were each analyzed using a chromameter and texture analyzer. Adding AOSC considerably decreased the calorie content of jelly by up to 35%, from 147 Kcal/100 g to between 94.74 and 104.18 Kcal/100 g. In comparison to the control, the addition of AOSC had the same degree of preference in practically every attribute and did not affect total preferences. Additionally, it raised the yellow-blue component (b* value) and the lightness (L* value), but decreased the red-green component (a* value). While the cohesiveness, gumminess, and fracture values of the jelly candy decreased and the hardness values increased, the addition of AOSC did not affect the springiness value. The results of this research will be crucial in the development of new food products, particularly those that are low in calories and appealing to customers due to their improved physical qualities.

1- Introduction

Food security relates to fulfilling a person's food and ensuring it is of sufficient quantity and quality, while also ensuring it is safe, diverse, nutritious, equitable, and affordable so that one can live a healthy and productive life [1]. Food security can be indicated by the number of nutritional problems in a country. According to UNICEF data, the prevalence of malnutrition, calculated from the number of stunting cases, reached 22.3% in 2022. This prevalence has decreased since 2020, but the decline is gentle at around 0.2-0.3% per year. On the other hand, between 2005 and 2022, the problem of overnutrition has not decreased, constantly at the number of 5.5%[2]. Based on this phenomenon, food security is still a global problem. Apart from insufficient food sources leading to malnutrition, welfare inequality also led to overnutrition in certain populations.

The prevalence of overnutrition is not as high as the prevalence of undernutrition, but this problem has not decreased from year to year. Handling overnutrition status is important because it risks the occurrence of metabolic diseases, such as diabetes mellitus (DM). This disease is still the cause of death in the world [3]. DM patients, apart from using drugs and herbs, can also use medical nutritional therapy. In medical nutrition therapy, it is important to pay attention to the regularity of the eating schedule, type, and number of calories of food consumed [4].

Low-calorie staple foods and snacks for people with DM have been developed. *Amorphophallus oncophyllus* (AO) or a tuber known locally as porang has a high concentration of the beneficial compound glucomannan, reaching 59-65% [5]. Glucomannan has been widely available and its demand has substantially increased. Its global market size in 2022 was reported at US dollar 1.47 Bn and is expected to reach US dollar 1.83 Bn in 2029 [6]. It is necessary because of its health benefits that has been investigated in several contexts. Research findings have validated the nutritional benefits of this food, including its ability to reduce weight by satisfying hunger and promoting fullness [7], control hyperglycemia, and hypercholesterolemia [8][9], and improve digestive tract health [10]. The application of glucomannan is becoming more widespread mainly in food and pharmaceuticals include encapsulation, emulsion, biodegradable film, thickener, binder, and many more [11].

However, the use of pure glucomannan is limited because of its great price. The consumption of raw AO may be considered as another way to consume glucomannan. Raw AO was more nutritious than pure glucomannan as particularly it not only contained carbohydrates and fiber, but also had protein, fat, mineral, and starch [12]. Unfortunately, there was calcium oxalate in raw AO that may cause itching and long-term consumption had a risk of kidney stones formation [13]. Naturally, the calcium oxalate in raw AO varies between 3.08-22.72% [14][15]. Several methods, such as the use of ball mills, stamp mills, fractionation blowers, and chemicals such as ethanol, ash, and sodium chloride, have been tried to reduce the amount of calcium oxalate in raw AO [16][17][18]. Another way to lower the calcium oxalate concentration of AO was to employ an herbal approach by maceration with a *Strobilanthes crispus* (SC) ethanolic extract. Preview research had demonstrated that it worked better than using ethanol by itself. By using this method, the lowest amount of calcium oxalate could be reached, which was 0.2% [13].

AO that has been macerated with an SC ethanolic extract had the special health benefits of reducing blood glucose levels which is comparable to glibenclamide (commercial drug) and was better than using AO alone [8]. The study of toxicity reported that AO macerated with SC ethanolic extract (AOSC) was safe to consume [19][20].

Raw AO has been widely applied to food products, but it still needs diversification to

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increase consumption. The development of jelly candy added with AOSC was carried out as a low-calorie food product. This study aimed to evaluate the sensory and physical properties of this jelly candy, including its color and texture.

2-MATERIALS AND METHODS

2.1. Materials

AO was obtained from the Porang Nusantara Activist Association branch of Boyolali, North Java, Indonesia. The AOSC was then produced based on an Indonesian submission patent (no S00202006668) [21].

2.2. Production of jelly candy with AOSC added

The jelly candy was made from 17.5% mixed gum (carrageenan, jelly flour, gelatin) and dragon fruit, corn sugar, citric acid, and strawberry flavor, based on an Indonesia submission patent (no S00202211830) [22]. The materials were mixed, cooked, and molded [23]. The AOSC was added in different concentrations (0, 0.2, 0.5, 0.7, and 0.9% for F0, F1, F2, F3, and F4, respectively).

2.3. Analysis of macronutrient and energy values

Macronutrient analysis was based on the Association of Official Analytical Chemists (AOAC) [24]. The energy values of jelly candy were then calculated using the Atwater factor [25].

2.4. Sensory analysis

The preferences for jelly candy were analyzed by hedonic test using 30 semi-trained panelists. The inclusion criteria of panelists were had passed the sensory lesson, were healthy, not drinking, not smoking, and were willing to be a panelist. The panelists were asked to eat the samples and write their preferences of color, taste, flavor, texture, and overall acceptance [26]. A five hedonic scale was used with 1 (extremely dislike), 2 (dislike), 3 (slightly like), 4 (like), 5 (extremely like).

2.4. Color measurement

The colors of jelly were expressed in three dimensions: lightness L*, redness a*, and yellowness b*. These colors were measured by using a chromameter CR-400 (Konica Minolta Business Technologies, Inc., Tokyo, Japan). The chromameter was adjusted for illuminant C. It was then standardized using a white reflector plate. The color of the jelly was measured by using the base material color measurement apparatus.

2.5. Texture profile analysis

A texture profile analysis was performed as hardness bite 1, gumminess, fracture, chewiness, cohesiveness, adhesiveness, and springiness index. These elements were analyzed using a CT3 texture analyzer (Brookfield Engineering Laboratories, Inc., USA).

2.6. Statistical analysis

Software called SPSS 16.0 was utilized for statistical analysis. A one-way analysis of variance (ANOVA) was used to analyze the data. Duncan's multiple range test (DMRT) was used to compare means at $p<0.05$.

3- RESULTS AND DISCUSSION

3.1. Macronutrient and energy values

Table 1. Macronutrient and energy values of jelly candy in different concentration of *Amorphophallus oncophyllus* macerated with *Strobilanthes crispus* (AOSC)

Macronutrient and Energy Values	F0	F1	F2	F3	F4
Fat (%)	0.46±0.01^{d}	0.07±<0.01^{c}	0.06±<0.01^{bc}	0.05±<0.01^{ab}	0.04±<0.01^{a}
Protein (%)	15.06±0.23	15.63±0.2	14.58±0.13^{a}	14.29±0.02	14.18±0.04

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	b	4c		a	a
Carbohydrate (%)	20.80±0.08 e	8.36±0.23 a	11.34±0.24 d	10.69±0.03 c	9.42±0.14b
Energy values (Kcal/100 g)	147.56±0.47e	96.58±0.09b	104.18±0.46d	100.35±0.03c	94.74±0.72a

Notes: F0, F1, F2, F3, and F4 were the jelly candy added AOSC with the concentration of 0 (control), 0.2, 0.5, 0.7, 0.9%, respectively. Means with distinctive letters within the same row are significantly different ($p<0.05$).

The addition of AOSC significantly reduced fat, protein, and carbohydrate levels when compared to controls ($p<0.05$) (Table 1). In detail, the more AOSC added to the jelly, the lower the fat and carbohydrate content, while the decrease in protein content only occurred with the addition of 0.2% AOSC. The addition of 0.5, 0.7, and 0.9% of AOSC did not result in a decrease in protein levels.

The values of the macronutrients might be used to calculate the calories. The calories in jelly were considerably decreased by up to 35% when AOSC was added, from 147 Kcal/100 g to approximately 94.74–104.18 Kcal/100 g. Jelly candy can be served as much as 10 grams for each consumption and contains around 9.47-10.42 Kcal per piece of jelly candy. The main focus of dietary energy restriction for the management and treatment of type 2 diabetes has been weight loss using low-calorie diets (1200–1500 kcal/day) or very low-calorie diets (about 400–800 kcal/day) [27]. Snack foods typically provide around 15% of daily energy needs [4] or around 225 Kcal per day. With a fairly low number of calories per item, 9.47-10.42 Kcal/candy, this jelly candy is safe for diabetes sufferers to consume up to around 21 pieces of candy per day.

3.2. Sensory properties

Thirty panelists scored the sensory attributes based on the preference or acceptance of color, flavor, taste, texture, and overall. The preference scores were above 3 in all sensory attributes which means jelly was slightly liked. Table 2 shows that the addition of AOSC did not affect the overall acceptance of jelly candy ($p>0.05$). In addition, for each attribute assessed, several formulas appeared to have the same level of preference compared to the control ($p>0.05$). For example, in the color attribute, adding AOSC to a concentration of 0.7% (F3) did not reduce the panelists' level of preference, as did the flavor attribute. Even on the texture attribute, the level of control preference was not significantly different from all treatments ($p>0.05$). The highest scores of preferences for taste and texture were observed in F3 samples. Some of the panelists commented that they received the taste of jelly candy mainly from dragon fruit. They also described the texture of jelly candy as less-chewy, but had the unique grainy texture from the presence of AOSC. The less-chewy may be caused by the inappropriate composition of polysaccharides in jelly candy, like gelatine, glucomannan in AOSC, and carrageenan [28]. In previous research, it was proven that konjac flour plays a role in forming a viscous solution, while κ-carrageenan forms a heat-induced, brittle (hard) gel upon cooling [29]. This sensory information is needed in the food industry to describe the acceptability of consumers [26].

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Table 2. Sensory properties of jelly candy in different concentration of *Amorphophallus oncophyllus* macerated with *Strobilanthes crispus* (AOSC)

Sensory Attributes	**F0**	**F1**	**F2**	**F3**	**F4**
Color	4.06±0.77 b	3.90±0.71 ab	3.87±0.63 ab	3.70±0.70 ab	3.57±0.82 a
Flavor	3.94±0.63 b	3.43±0.77 a	3.60±0.72 ab	3.53±0.94 ab	3.20±0.89 a
Taste	4.00±0.86 c	3.40±0.77 ab	3.40±0.81 ab	3.73±0.83 bc	3.13±0.97 a
Texture	3.42±0.99 ab	3.23±0.63 a	3.53±0.94 ab	3.73±0.87 b	3.20±0.89 a
Overall acceptance	3.68±0.65 a	3.33±0.66 a	3.57±0.77 a	3.70±0.75 a	3.33±0.99 a

Notes: F0, F1, F2, F3, and F4 were the jelly candy added AOSC with the concentration of 0 (control), 0.2, 0.5, 0.7, 0.9%, respectively. Means with distinctive letters within the same row are significantly different ($p<0.05$).

3.3. Color properties

Based on Figure 1, the lightness (L*) values of jelly candy were in the range of 17.53–20.64, which indicated white. Some treatment groups like F1 and F2 had lower values than the control, while F3 and F4 had the same value as the control. This indicates that the higher concentration of AOSC could increase the brightness of the candy. The jelly candy used in this study had a dark purple coloration due to the addition of a natural colorant from dragon fruit. Theoretically, there were also yellow carotene and polyphenols in the AOSC that were susceptible to oxidation, which resulted in a brown color [30][31][32].

The a* values of the control was declined significantly compared to the treatment group ($p<0.05$), yet the treatment groups had almost the same values in the range of 3.85–6.27 (Figure 1). The a* values indicated the red colors of the jelly. The red color in the jelly candy is influenced by the betacyanin pigment of the dragon fruit [33]. The addition of AOSC reduced the concentration of betacyanin in the candy, thus reducing the redness.

The b* values of the candy were in the range of 4.54–4.88 (Figure 1). The addition of AOSC resulted in a bit higher of b* values. The b* value indicated the blue color. This may have been caused by the degradation of the color pigment, which may have resulted from the heating process [33].

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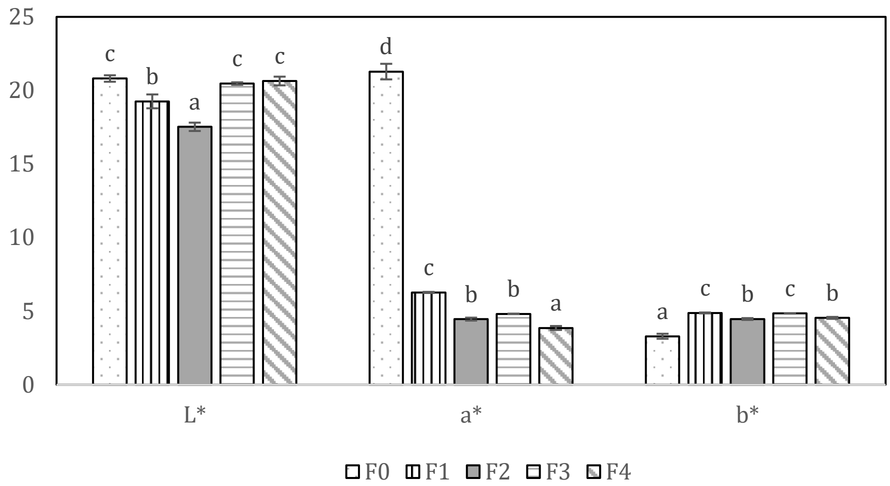

Fig 1. Three dimensions colors of the jelly candy in different concentration of *Amorphophallus oncophyllus* macerated with *Strobilanthes crispus (*AOSC): L* (lightness), a* (redness: green to red), b* (yellowness: blue to yellow). F0, F1, F2, F3, and F4 were the jelly candy with the concentration of AOSC 0 (control), 0.2, 0.5, 0.7, 0.9%, respectively. Various letters (a, b, c) in a group representing the significant difference among the groups ($p < 0.05$)

3.3. Texture profile

Table 3 shows the effect of AOSC concentration on the texture profiles of the jelly candy. In this study, the addition of AOSC increased the hardness values of jelly candy, proven by the significant differences between treatment samples and control ($p<0.05$). The hardness values decreased gradually and significantly with increasing concentrations, from 56.4 N in F1 to 19.42 in F4 ($p<0.05$). This observation is different from that of previous research that used carrageenan and pectin as hydrocolloids. It was reported that hardness increased with increasing hydrocolloid concentration [34]. Glucomannan is an active compound that has been proven to have the ability to absorb up to 200 mL of water per gram [35] and form a gel [36]. This water absorption ability was influenced by the hydroxyl, carbonyl, and acetyl groups [36]. The gel-forming ability of glucomannan was synergistic with that of carrageenan [37] to form the helical carrageenan and konjac molecules through hydrogen bonding. However, the high interaction between the two gums, particularly at the junction zones, could cause the konjac to stay un-gelled and alter the viscosity characteristics, which would reduce the gel hardness [29]. Moreover, the addition of AOSC decreased the concentration of carrageenan, which increased the gel strength of the candy [34]. The strong hydrogen bonds in glucomannan affected its inability to absorb water, resulting in incomplete gel formation.

The cohesiveness values of candy added with AOSC were in the range of 0.62–0.67 (Table 3). F1 was not significantly different from F2 and F3. Only F3 showed a value different from that of F4. All of the samples were lower than the control ($p<0.05$). This value is relatively higher than those reported in a previous study that used carrageenan and pectin (0.31–0.33) [34]. The cohesiveness values indicated internal bond strength, so the lower the value, the smaller the internal bond strength, and the easier it is to chew [38].

The adhesiveness values of the jelly candy (Table 3) were not significantly different in all AOSC concentrations, including the control ($p > 0.05$). This indicates that the addition of AOSC did not change the adhesiveness value. The adhesiveness values represented the degree of stickiness or ability to adhere to surrounding items, like plates and packaging, for the candy. [39]. Compared to the results of a prior study that used gelatin as a

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hydrocolloid, this was relatively higher [40].

The addition of AOSC affected the gumminess of jelly candy. It declined with the increasing AOSC concentration ($p < 0.05$) (Table 3). This value was positively related to the hardness value and is defined as the energy required to reduce the size of food [28,34]. In this study, the gumminess values appeared to significantly decline from 35.11 to 13.05, which was in line with the reduction in hardness values. These values were also lower than those of other candies made with hydrocolloids of carrageenan and pectin [28]. This was due to the different ratios of carrageenan and konjac used. Moreover, konjac was used as pure flour, whereas AO was used as raw flour.

The fracture values of the jelly candy were affected by the addition of AOSC. It was lower when the AOSC was added ($p<0.05$) (Table 3). On the other hand, almost all the treatment samples had the same values in the range of 2.09-2.64 N. The lower fracture value was related to the ease of the candy being broken [41].

The springiness values were generally not significantly different in almost all samples, with the values ranging from 0.89 to 0.92, except for F3, which proved to be the lowest ($p < 0.05$) (Table 3). These values were often related to the elasticity, that is, the ability to return to the original shape after deformation. The springiness value in this study had the same tendency as in previous research, especially because it was inversely proportional to the hardness value [28].

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Table 3. Texture profiles of jelly candy with different concentrations of *Amorphophallus oncophyllus* macerated with *Strobilanthes crispus* (AOSC)

Texture parameters	F0	F1	F2	F3	F4
Hardness bite 1 (N)	39.30±0.32^{b}	56.40±5.27^{d}	47.58±1.62^{c}	41.08±3.16^{b}	19.42±1.41^{a}
Cohesiveness	0.74±0.02^{d}	0.62±0.30^{ab}	0.66±0.03^{bc}	0.60±0.01^{a}	0.67±0.03^{bc}
Adhesiveness (Nmm)	0.86±0.32^{a}	0.47±0.28^{a}	0.80±0.20^{a}	0.93±0.45^{a}	0.78±0.24^{a}
Gumminess	28.90±0.98^{c}	35.11±2.23^{d}	31.19±0.75^{c}	24.51±2.44^{b}	13.05±0.55^{a}
Fracture (N)	14.11±0.01^{a}	2.64±0.19^{bd}	2.44±0.09^{cd}	2.37±0.12^{c}	2.09±0.15^{b}
Springiness index	0.92±0.01^{c}	0.91±0.02^{bc}	0.91±0.01^{bc}	0.87±0.02^{a}	0.89±0.01^{b}

Notes: F0, F1, F2, F3, and F4 were the jelly candy with the concentration of AOSC 0 (control), 0.2, 0.5, 0.7, 0.9%, respectively. Means with distinctive letters within the same row are significantly different ($p<0.05$).

4- CONCLUSIONS

This study found that the addition of AOSC significantly reduced the calorie values in jelly by up to 35%, from 147 Kcal/100 g to around 94.74-104.18 Kcal/100 g. The addition of AOSC did not affect the overall acceptance and had the same level of preference in almost each attribute compared to the control. It also increased the L* value (lightness) and the b* value (yellow-blue components), but decreased a* value (red-green component). The addition of AOSC did not affect the springiness value, but increased the hardness values of jelly candy and declined the cohesiveness, gumminess, and fracture values. This research is important for developing new food products, especially as a low-calorie food that is acceptable to consumers with the quality improvement in physical properties.

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6-CONFLICT OF INTEREST AND FUNDING DISCLOSURE

All authors have no conflict of interest in this article. The Indonesian Ministry of Education, Culture, Research, and Technology, Directorate General of Higher Education, Research, and Technology (DRTPM) provided funding for this study under PTUPT Funding 2023.

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