Physicochemical Characteristics of Bun Made from Orange-Fleshed Sweet Potato Clones

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Abstract. Sweet potato tubers are source of carbohydrates, vitamins, minerals, dietary fiber, beta-carotene, anthocyanins, and other phenolic components. Beta-carotene has been promoted because of its high antioxidant activity and health benefits. The research activity was aimed to determine the suitability of orange sweet potato as a substitute material for bun making. The texture characteristics of MSU 14011-09 showed the highest chewiness value compared to the other three varieties and one clone. Beta-carotene levels of mashed orange sweet potatoes varied. The highest value was found in Beta 1 (12,601µg/100g, dw) and the lowest was MSU 14011-09 (3,561µg/100g, dw. Beta-carotene affects the color of mashed sweet potatoes. The bun made from Beta 2 and MSU 14011-09 had low moisture content and high yield, whereas the bun from Beta 2 had high cohesiveness. Beta 1 produces buns with high L, a*, and b* values, whereas Beta 2 and MSU 14011-09 produce buns with low L, a*, and b* values. The lower the a* and b* value of Bun, the higher the color preferences of the panelists. Beta 2, Beta 3, and MSU 14014-84, were suitable for bun production.
Keywords: Sweet potato, buns, physical, chemical

1 Introduction

The sweet potato (*Ipomoea batatas*) is a nutritious crop that can be processed into many kinds of value-added products; include French fries, chips, frozen dices, purees, canned and dried foods. [1]. Sweet potatoes have been demonstrated to exhibit multiple health benefits closely related to their high contents of proteins, vitamins, carotenoids, polyphenols, minerals, and other bioactive compounds with antioxidant properties [2][3]. Sweet potato varieties can be indicated based on the color of the tuber flesh, namely white, orange, and red, to purple [4]. One of several types of sweet potatoes that are spread across Indonesia is the orange sweet potato. As the name implies, the color of the flesh of the tuber is orange. Provitamin A is mostly obtained from cultivars with orange-colored fleshed tubers that contain high levels of carotenoids [5].

The intensity of the color has a positive correlation with the beta-carotene content, where the darker the yellow or orange color of the tuber, the higher the beta-carotene it contains [6]. Beta-carotene is the main carotenoid compound in sweet potatoes which has vitamin A activity (100%), the highest among other carotenoids [7][8]. In comparison to

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pumpkin (490-1,500µg/100g) and carrots (7,975-8,840µg/100g) [9], orange sweet potatoes have a higher beta-carotene content of 79.5-91.7% [10], or 20,000 g/100g fresh weight base (fwb).

Beta-carotene can be regarded as an antioxidant because it can prevent or slow down the occurrence of oxidative damage in the body. Oxidative damage, which generates free radicals, is what causes diseases like CHD (Cardiovascular Heart Disease), retinal degeneration, diabetes, and cancer, etc. As free radical scavengers, antioxidants prevent and repair damage caused by free radicals [11]. Beta-carotene has antioxidant activity that can inhibit aging, cancer, and heart disease [12] and can improve the function of the immune system [13].

By promoting the health benefits and taking advantage of the availability of various alternative sweet potato-based food products, it will be feasible to increase the value of consumption, improve public health, and support local food diversification programs at the same time. As a source of carbohydrates, sweet potato has high potential as a raw material for flour, especially as a substitute for wheat flour in flour-based products, especially for bread products. The availability of numerous different food products made from sweet potatoes and the promotion of sweet potatoes as health benefits can improve public health, stimulate consumption, and contribute to regional food diversification efforts.

Currently, Beta 1, Beta 2, and Beta 3 types of sweet potatoes have been widely commercial [14]. In addition, there are two promising sweet potato lines (MSU 14011-09 and MSU 14014-84) with yield potentials above 35 t/ha and various intensities of orange color as a result of breeding projects.. Clones must be evaluated to determine whether they are suitable for food products before being released as a new variety so that consumers would accept them. In this study, buns were made using three varieties and two clones of orange-fleshed sweet potatoes as substitutes of wheat flour, and their appropriateness was assessed in terms of their physical and sensory qualities. The selection of orange sweet potato as a substitute material is intended to increase the use of sweet potatoes for other materials to reduce the need for wheat flour and increase the content of beta-carotene in the final product.

2 Methodology

Five orange-fleshed sweet potatoes consisting of three varieties (Beta 1, Beta 2, and Beta 3) and two promising lines, namely MSU 14011-09 and MSU 14014-84, were harvested 4–4.5 months after they had been planted in Malang, Indonesia. Fresh tubers were rinsed with water and steamed for 15 minutes, and Texture Profile Analysis (TPA) method was applied to determine the textural properties [15]. Fresh tubers were cleaned, cooked for thirty minutes, peeled, and mashed prior to being made into mashed sweet potatoes. Mashed sweet potatoes were observed for their moisture [16], reducing sugar [17], beta-carotene content [18], and the colors (L*, a*, b) [19] in the Indonesian Legumes and Tuber Crops Research Institute (Iletri), Malang, at the Food Chemistry Laboratory.

Mashed sweet potato is mixed with wheat flour with an amount of 30% of the total. In the bun making activity, bun dough is made by mixing 700 grams of wheat flour with 300 grams of mashed sweet potato, dried yeast, improver, salt, and water. For the buns, characteristics were also analyzed, including moisture content, yield recovery, porosity, colors, and also texture profile characteristics. The hedonic method was used to evaluate the level of preference for sensory bun attributes (color, aroma, taste, and texture) by 25 untrained panelists [20]. The scores that follow are used to evaluate a liking: 1 = Dislike very much, 2 = Moderately Dislike, 3 = Slightly Like, 4 = Moderately Like and 5 = Like very much.

Five replicates of the trial were carried out and the design of the study was Complete Randomized Design. To determine the differences between the materials examined, data were analyzed using an ANOVA test, followed by an LSD test at a 5% level.

3. Result and discussion

3.1 Texture profile characteristic steamed sweet potato tubers

The texture profile of food crops is an important characteristic, including root crops. Characteristics of the texture profile of sweet potato are very important to describe its properties when the tuber is subjected to the heating process. In general, the texture properties of a clone are specific and different compared to other clones. Texture properties of sweet potatoes as a result of breeding activities in Japan can be classified into five categories: mealy, slightly mealy, intermediate, slightly soggy, and soggy [21]. Differences in the texture characteristics of raw materials will cause differences in the texture characteristics of the product when it is continued with further processing.

Table 1. Texture profile characteristics of 5 orange sweet potato varieties/clones

Varieties/clones	Hardness (N)	Adhesiveness (N)	Springiness (%)	Cohesiveness (N)	Chewiness (N)
Beta 1	7.70 ± 0.64 b	0.01 ± 0.01 ns	55.29 ± 3.32 ns	0.24 ± 0.03 ns	102.04 ± 19.15 b
Beta 2	2.58 ± 0.17 c	0.67 ± 1.16	73.86 ± 19.03	0.14 ± 0.04	25.12 ± 4.49 b
Beta 3	7.53 ± 1.08 b	0.78 ± 0.84	74.80 ± 7.43	0.12 ± 0.04	72.37 ± 36.38 b
MSU 14011-09	19.54 ± 2.90 a	0.02 ± 0.01	81.68 ± 13.00	0.20 ± 0.07	312.62 ± 84.23 a
MSU 14014-84	9.59 ± 0.94 b	0.07 ± 0.08	80.76 ± 8.97	0.13 ± 0.07	105.37 ± 61.70 b
LSD value	2.69	1.14	21.18	0.10	91.38

Notes:
Values in one column followed by a different letter are statistically different at $P<0.05$.
ns: not significant

A material's hardness is a physical characteristic that determines how easily it will deform when put under strain. The findings revealed that sweet potato clones had considerably varying hardness values (Table 1). Water content generally affects hardness; the less water present, the harder the material is. However, other elements found in tubers, such as variations in the amount and type of carbohydrates they contain, can also affect hardness. Fiber can also affect how hard something is measured [22]. The maximum hardness value was discovered in MSU 14011-09, while the lowest was discovered in Beta 2.

Adhesiveness is the amount of force required to break the bond that develops between a substance's surface and the surface of an attached material. The range of the investigated sweet potato clones' adhesiveness, from 0.01 to 0.78 N, did not differ significantly from one another. The gelatinized starch produces a gel during the steaming process, which can enhance the viscosity, giving tubers their sticky characteristics [23].

Determining the product's elasticity, springiness is defined as how well a product recovers from deformation after the deforming force has been removed [24][25]. The springiness value of the five orange sweet potato clones did not differ considerably, varying from 55.29% to 81.68%. The moisture content will affect the value of springiness in this

case. In this case, the moisture content will determine the value of springiness. A high springiness indicates that the texture is more elastic [26].

According to Table 1, there was no significant difference in the cohesiveness values of the sweet potato clones in the range of 0.12 to 0.24N. This shows that the 5 tested clones exhibit the same level of deformation before the material fractures.

Chewiness is defined as the result of calculating the values of hardness, cohesiveness, and springiness (Chewiness = hardness x cohesiveness x springiness). Generally, chewiness is the energy needed to break down solid food into a state ready to be swallowed [27]. Results showed that the chewiness value varied significantly different, and ranged from 25.12 to 312.62N (Table 1). The chewiness values of the MSU 14014-84, Beta 1, Beta 2, and Beta 3 clones were low and not significantly different; however, the chewiness value of MSU 14011-09 was the highest and significantly different from the other 4 clones tested.

Chewiness value is related to hardness [28]. The hardness value of MSU 14011-09 is quite high, and the chewiness of the genotype is also high. Beta 2 has the lowest hardness value, so chewiness was also low. In addition, the observation also shows that chewiness is also influenced by springiness and cohesiveness.

3.2. The characteristics of mashed sweet potato mashed

The moisture content of paste sweet potato has a significant role in determining the quality of the following processed products. Based on Table 2, the moisture content of the Beta 3 had the lowest value and was followed by 4 other clones tested, while Beta 2 had the highest. Compared to fresh tubers, sweet potatoes' moisture content might be lower after steaming. This occurs as a result of the gelatinization process's evaporation [29][30]. The effect of the difference between the five types used as raw materials for buns is, however, fairly not much.

Table 2. Moisture, reducing sugar, beta-carotene content, and color attributes of mashed sweet potato

Varieties/clones	Moisture (%)	Reducing sugar (%)	Beta-carotene (µg/100g, dw)	L* (%)	a*	b*
Beta 1	77.76 ± 0.06 b	18.36 ± 0.43 b	12,601 ± 817 a	49.7 ± 0.15 d	45.8 ± 0.47 b	39.8 ± 0.68 c
Beta 2	78.29 ± 0.05 a	15.72 ± 0.18 d	6,142 ± 1,188 b	53.8 ± 0.06 c	35.1 ± 0.12 e	41.7 ± 0.65 b
Beta 3	66.94 ± 0.06 e	18.31 ± 0.13 b	4,354 ± 464 cd	59.6 ± 0.15 a	47.6 ± 0.06 a	50.1 ± 0.78 a
MSU 14011-09	75.61 ± 0.14 c	17.65 ± 0.22 c	3,561 ± 37 d	57.4 ± 0.21 b	42.9 ± 0.30 d	40.5 ± 0.55 bc
MSU 14014-84	74.66 ± 0.03 d	19.65 ± 0.31 a	5,382 ± 148 bc	54.0 ± 0.72 c	44.9 ± 0.61 c	40.2 ± 0.83 c
LSD value	0.14	0.51	1,239	0.63	0.68	1.28

Notes:
Values in one column followed by a different letter are statistically different at $P<0.05$
dw = dry weight
L*: lightness level, ranges from 0 (dark/black) to 100 (light/white)
a*: redness level, ranges from green (-100) up to red (+100)
b*: yellowness level, ranges from blue (-100) up to yellow (+100)

Reducing sugar is a component contained in sweet potatoes. The native amylase enzyme, which is active when starch is gelatinized at its activity temperature, causes the reducing sugar content to increase during steaming. High concentrations of amylases, mainly α- and β-amylase, are present in sweet potato roots and have a considerable impact on the sugar content of processed sweet potatoes [31]. The levels of reducing sugar contained in 5 mashed sweet potatoes were sequentially from the highest, namely MSU 14014-84, Beta 1, Beta 3, MSU 14011-09, and the lowest was Beta 2.

The beta-carotene content in mashed sweet potatoes is presented in Table 2. Beta-carotene levels of mashed orange sweet potatoes were significantly different between sweet potato clones, while the highest value was found in Beta 1 (12,601µg/100g, dw), and the lowest was MSU 14011-09 (3,561µg/100g, dw) and similar to Beta 3 (4,354µg/100g, dw), whereas 2 others have moderate levels of beta-carotene contents. In general, beta-carotene will decrease due to the heating process. Steaming the fresh tubers for 10 to 50 minutes may cause about 50% decrease in the amount of beta-carotene [32]. Beta-carotene in carrots also decreased after boiling [33]. Heating causes beta-carotene to isomerize from the form trans to cis, thereby reducing the content of beta-carotene [34]. Hot air circulation in the steaming process could stimulate the degradation of beta-carotene due to the interaction of oxygen with beta-carotene [35][36].

For the color attributes of mashed sweet potato, the Lightness value (L*) was significantly different for all clones studied, with the highest value in Beta 3 (59.6%), followed by MSU 14014-09 (57.4%), MSU 14014-84 (54.0%), Beta 2 (53.8%), and Beta 1 (49.7%). Another color characteristic, redness (a*), was highest in Beta 3, followed by Beta 1, MSU14014-84, and MSU 14011-09, and Beta 2 had the lowest value. In terms of yellowness, Beta 3 is notably different from other clones and has the highest b*. The beta-carotene content influences the color of mashed sweet potatoes. The higher the L* values, the lower beta-carotene content [6]

3.3. Physical and organoleptic attributes of sweet potato buns

The physical qualities of buns prepared from five different raw materials have been evaluated. Table 3 summarizes the findings in terms of moisture content and the physical characteristics of the produced buns. The moisture content of the buns made from Beta 1 and Beta 3 was higher compared to those made from the other three clones. This is in line with the moisture level in the mashed sweet potato that was used. The greater the moisture contents of the raw material, the lower the moisture content of the product.

This, however, is not in line with the Yield of produced buns. Yield is the change in weight of the dough before steaming and after steaming. The buns prepared from Beta-2, and MSU 14011-09, which had the lowest amount of water in them, produced the highest yield. MSU 14014-84 has the same moisture content as Beta-2 and MSU 14011-09, but a lower yield and a higher number of pores. This could be due to changes in the amylose and amylopectin components of the three clones' starch. During the steaming and mashing processes, the tubers will gelatinize, followed by hydrolysis of starch by endogenous enzymes found in sweet potatoes, producing the fragments of carbohydrate polymers of varying sizes. This is assumed to be the reason for the difference in yield and number of pores in MSU 14014-84 buns compared to Beta-2 and MSU 14011-09 after mixing and cooking the dough.

Table 3. Moisture content and physical properties of buns

Varieties	Moisture (%)	Yield (%)	Pores/cm2	L* (%)	a*	b*
Beta 1	40.28 ± 0.09 b	103.16 ± 1.15 b	68 ± 4.16 cd	73.1 ± 0.70 ns	48.0 ± 0.06 a	46.0 ± 0.76 a
Beta 2	38.71 ± 0.05 c	115.90 ± 1.71 a	64 ± 2.65 d	73.8 ± 1.25	42.4 ± 0.17 d	40.2 ± 0.12 c
Beta 3	41.82 ± 0.28 a	101.63 ± 0.69 b	83 ± 6,24 b	72.5 ± 0.81	44.8 ± 0.20 c	45.0 ± 0.49 a
MSU 14011-09	38.52 ± 0.10 c	114.59 ± 1.38 a	78 ± 4.73 bc	73.8 ± 1.78	42.2 ± 0.40 d	40.5 ± 0.20 c
MSU 14014-84	38.77 ± 0.10 c	103.38 ± 1.70 b	105 ± 9.17 a	73.6 ± 1.11	45.5 ± 0.17 b	43.5 ± 0.72 b
LSD value	0.29	2.23	11.95	2.43	0.45	1.1

Notes:
Values in one column followed by a different letter are statistically different at $P<0.05$
ns: not significant
L*: lightness level, ranges from 0 (dark/black) to 100 (light/white)
a*: redness level, ranges from green (-100) up to red (+100)
b*: yellowness level, ranges from blue (-100) up to yellow (+100)

Consumers are going to realize color as an essential visual attribute. The color of the buns made from 3 varieties and 2 clones of orange sweet potato is a product that needs to be studied and developed based on the orange color of the buns obtained. The color criteria for the resulting buns were tested based on the level of L*, a*, and yellowness b* values. Buns produced from 5 orange sweet potato clones had high L values (72.5 – 73.8%), and all of them did not show a significant difference, this was due to the shiny surface of the buns. In comparison with the other buns, Beta 1 made buns have the highest levels of a* and b*. This is because of Beta 1's high beta-carotene content that gives it an intense orange hue. Sweet potatoes mashed from Beta 2 and MSU 14011-09 have low a* and b* values with low orange intensities, resulting in buns with low a* and b* intensities. Based on correlation analysis ($y=0.31x+30.97$; $R^2=0.41$), the intensity of a* and b* in mashed sweet potatoes generally has no effect on the values of a* and b* in Bun.

Table 4. Texture profile characteristic of buns made from 5 sweet potato varieties/clones

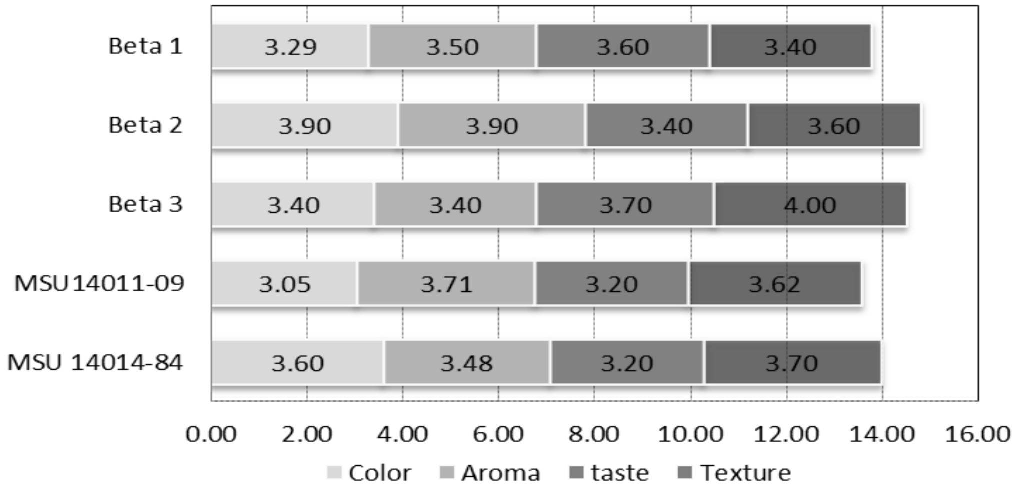
Varieties	Hardness (N)	Adhesiveness (N)	Springiness (%)	Cohesiveness (N)	Chewiness (N)
Beta 1	3.49 ± 0.44 ab	0.05 ± 0.08 b	41.20 ± 8.47 ns	0.72 ± 0.07 ab	103.84 ± 31.46 ns
Beta 2	2.93 ± 0.26 b	0.03 ± 0.02 b	43.52 ± 10.76	0.86 ± 0.04 a	107.53 ± 12.92
Beta 3	4.35 ± 1.34 a	0.05 ± 0.08 b	50.83 ± 4.17	0.57 ± 0.14 bc	125.61 ± 45.57

MSU 1401 1-09	4.16 ± 1.34 ab	0.03 ± 0.02 b	47.49 ± 2.50	0.50 ± 0.13 bc	102.46 ± 49.31
MSU 1401 4-84	3.68 ± 0.23 ab	0.28 ± 0.25 a	49.44 ± 5.85	0.48 ± 0.14 c	85.00 ± 17.82
LSD value	1.33	0.16	11.91	0.22	69.63

Notes:
Values in one column followed by a different letter are statistically different at $P<0.05$
ns: not significant

The physical elements that a product possesses are the texture profile characteristics. Table 4 shows the results of a texture test examined on buns made from five various varieties of orange sweet potatoes. The tested buns had springiness and chewiness that were not significantly different. The bun made from Beta 2 had the lowest hardness compared with the other four clones, which had the same hardness. This can be affected by the two properties of mashed sweet potatoes. Mashed potato Beta 2 has the lowest hardness and highest water content, so the steamed bun dough produces soft buns. In addition, the bun from Beta 2 has a few pores, and it is suspected that these pores are large in size, so the bun body has soft properties when tested. The cohesiveness bun from Beta 2 has the highest value, this shows the degree to which a material can deform before breaking, which is also high. The chewiness values demonstrated that although the five orange sweet potatoes differed in cohesiveness and hardness, their softness and chewing capability were similar. This indicated that even if the five sweet potato clones were substituted to produce the five buns, their physical characteristics were uniform.

Based on the organoleptic test, panelists' preferences for bun color ranged from "slightly liked" to "moderately like". Buns made from Beta 2 and MSU 14014-84 have a high value, this is in line with the bright bun color (high L) and moderately orange (low a* and b*). The aroma of a bun produced from five sweet potato clones was quite acceptable, while Beta 2's aroma was given the highest score. For the taste, the panelist did not specifically indicate a preference for sweet potato buns prepared from five different clones. The sweet potato clones did not appear to influence the taste of the buns, but rather the ingredients that were used to produce the buns, which were all added in the same amount. Texture is a sensory attribute that reflects the strength of the energy required to chew food. The panelists also did not seem to express their preference for the texture of buns made from the five sweet potato clones. The scores given by the panelists ranged from above "lightly like" (3.40) to "moderately like" (4.00). Based on the organoleptic test on the four criteria performed on buns produced from five sweet potato clones, the panelists preferred the buns produced from Beta 2, followed by Beta 3 and MSU 14014-84 (Fig.1).



Notes: Scores of preferences for color, aroma, taste, and texture:
1. Strongly dislike 3. Slightly like 5. Strongly like
2. Moderately dislike 4. Moderately Like

Fig 1. Hystogram total of sensory attributes given by panelist.

4 Conclusion

Characteristics of 3 varieties and 2 clones of sweet potato used as raw material for buns have different texture characteristics.

The beta-carotene concentration of sweet potatoes has been demonstrated to alter the orange color of the bun. High beta-carotene levels increased the intensity of redness and yellowness in the buns produced while also influencing panelists' preference for the buns studied.

Orange-fleshed sweet potato genotypes showed promising potential for use as bun ingredients. The genotypes with a light orange flesh color, Beta 2, Beta 3, and MSU 14014-84, were suitable for bun production.

Beta 1 with deep orange color and MSU 14011-09 with lightless orange color; both were tailored for the ingredients of other products. This information needs to be taken into account by the breeder in releasing new orange sweet potato varieties in addition to their excellent agronomic traits.

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