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Physical quality characters of cookies produced from composite blends of wheat and sweet potato flour

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Abstract. A research study was carried out to develop cookies with good nutritional and physical quality from sweet potato flour and wheat flour and to evaluate the quality characteristics. The mature sweet potato (cv. Wariapola Red) tubers were washed, peeled, cut into thin slices of 1mm thickness, dried under the sun until the pieces were quite brittle, milled and sieved. Different composite blends of wheat flour and sweet potato flour were mixed in the ratios (w/w) of 100:00, 80:20, 60:40, 40:60, 20:80 and 00:100. Cookies were then prepared from separate mixtures following manufacturing procedures. Sweet potato flour was nutritionally analyzed and it contained 2.3% protein, 9.4% dietary fiber and 85.5% soluble carbohydrate, and therefore, sweet potato flour appeared to be suitable for a successful combination with wheat flour for the production of cookies. Physical characteristics such as thickness, volume, diameter and spreading factor of the cookies decreased from 0.969 to 0.910 cm, 41.66 to 30.41 cm^3, 7.4 cm to 6.52 cm and 6.43 to 5.61 respectively while density of cookies increased from 0.474 g/cm^3 to 0.652 g/cm^3 with increasing of sweet potato flour up to 100%. The sensory qualities showed that the cookies supplemented with 40% sweet potato flour were well acceptable in terms of colour, texture, taste and overall acceptability. The mixture of 40% sweet potato flour and 60% wheat flour had been successful for the formulation of composite cookies with better physical, nutritional and organoleptic qualities within the universally accepted standards.

Keywords. Cookies, physical characters, organoleptic qualities, sweet potato flour, wheat flour.

1 Introduction

Sweet potato (*Ipomoea batatas*) is an extremely versatile and delicious vegetable that possesses high nutritional value (Mohanraj and Sivasankar

2014). Among the world's major food crops, sweet potato produces the highest amount of edible energy per hectare per day (Sukhcharn *et al.* 2008). Sweet potato consists of about 70% carbohydrates (dry basis) of which a major portion is starch, which can be utilized as a functional ingredient in certain food preparations (Avula 2005). It is an excellent source of vitamin A (in the form of beta - carotene) and also a very good source of vitamin C and Manganese. In addition, sweet potatoes are a good source of dietary fiber, natural sugars, protein, niacin, vitamin B5, vitamin B6, vitamin E, potassium, biotin, iron, calcium and copper ("The world healthiest foods", 2017).

Sweet potato is commonly referred to as a subsistence, food security or famine relief crop. Its uses have diversified considerably in the developing countries. Sri Lanka has a long history of cultivation of sweet potatoes. It is considered as a crop of exotic origin, but people regard it as indigenous because it has been in cultivation in Sri Lanka as an important traditional food crop since ancient times (Karunathilake 2005). Options for sweet potato products are numerous, and based on recent diagnostic assessments carried out in developing countries, dried chips, starch and flour have been identified as among the most promising products (Collins 1989).

The raw material of foremost importance in bakery product is the wheat flour. Wheat is the main raw material for bakery, biscuit and paste (Diana *et al*. 2007). Bakery products are commonly made from wheat flour containing gluten, whereas gluten contributes to the typical texture, flavour and form of the usual bread and cake products. Without gluten, baked goods will not hold their shape. That is why wheat flour is used in baking. There is however circumstances in which wheat flour are not readily available, or if people in these areas nevertheless wish to change to the consumption of the bread so that they will need to import wheat and pay for it.

A mixture of wheat flour and sweet potato flour could make a good baking product, which should increase its economic value (Zuraida 2003). Most of the technical research on sweet potato flour focused on the development of new products using sweet potato flour rather than on efficient methods to produce and store the flour (Lizado and Guzman, 1982; Sukhcharn *et al.* 2008). Addition of various proportion of sweet potato flour in wheat flour can increase the nutritive values in terms of fiber and carotenoids and also helps in lowering the gluten level and prevent humans from coeliac disease (Tilman *et al*. 2003).

Sri Lanka has a long history of sweet potato cultivation. Extent and production of sweet potato are 3,270 hectares and 25,780 metric tons in 2010 (Department of Census and Statistics of Sri Lanka, 2010). Sweet potato can be grown successfully throughout the year in all agro-ecological zones. In Sri Lanka, they are cultivated in all the districts but mainly in Ratnapura, Hambantota, Kurunagale, Gampaha, Kagalle, Badulla and Kalutura districts. In dry zone the cultivation area of sweet potato is low compared to wet zone

and intermediate zone (Department of Census and Statistics of Sri Lanka, 2010). It is considered as a crop of exotic origin, but people regard it as indigenous because it has been in cultivation in Sri Lanka as an important traditional food crop from very ancient time (Karunathilake 2005).

Sweet potato based products are of high quality and could compete with the existing products in the market (Sneha *et al.* 2012). The use of sweet potato flour for supplementing with wheat flour in the bakery industry could substantially reduce the need for wheat being imported, reduce the usage of sugar on the products and increase the value of sweet potato. The objective of present study is to replace the wheat flour in cookies with sweet potato flour (gluten – free flours) in order to increase the fiber and other nutrients and develop cookies resembles as closely as possible to the wheat flour based product.

2 Materials and Methods

2.1 Procurement of materials

Fresh sweet potatoes (Wariapola Red) without any bruises were procured locally from the field of commercial grower. Roots were washed, trimmed and cured to make them free from soil and other foreign materials, rotting or insect damage. Trimming was carried out manually and curing was done at 35°C for 2–3 days, stored at 12-15°C at 80% relative humidity till further use. Other major ingredients i.e. wheat flour, sugar, baking powder, salt and margarine were purchased from the super market of Batticaloa.

2.2 Preparation of sweet potato flour

Purchased sweet potatoes (cv. Wariapola Red) were washed, peeled and cut into thin slices at around 1mm thickness. Drying of sweet potato slices was done on perforated trays in the sun until the pieces were quite brittle and then stored in air tight container till further use. The dried chips were milled into flour using electric mill grinder (Aikeleyisi, flat wheel grinder) and passed through sieves (250 µm) to obtain flour of uniform size. The flour was then packed in air tight container and stored under ambient conditions until further use.

2.3 Experimental plan

Following types of cookies were made, and designated as T_1 to T_6.
T_1 - 100% wheat flour

T_2 - 20g Sweet potato flour /80g wheat flour (20+80 g)
T_3 - 40g Sweet potato flour /60g wheat flour (40+60 g)
T_4 - 60g Sweet potato flour /40g wheat flour (60+40 g)
T_5 - 80g Sweet potato flour /20g wheat flour (80+20 g)
T_6 - 100% sweet potato flour

2.4 Development of wheat and sweet potato blend cookies

Cookie dough was prepared according to the following formula: 100 g of flour (contain different proportion of sweet potato flour and wheat flour), 50 g of sugar, 20 g of margarine, 2 g of baking powder, 0.5 g of sodium chloride and various proportion of water to make required consistency of dough. The firm dough was rolled out to 5 mm thickness in a baking tray and cut into round having 7.4 cm diameter with a cookie cutter. The cookies were placed on a greased aluminum tray and baked in a pre-heated oven at 200 ^{0}C for 10 minutes to produce cookies. These cookies were assessed for physico-chemical and organoleptic qualities.

2.5 Determination of physical characteristics of wheat- sweet potato flour composite cookies

Physical parameters of wheat – sweet potato cookies were measured such as diameter (mm by Vernier caliper, Mitutova, Japan), and thickness (mm) and other parameters such as volume, density and spread ratio were determined as follows.

Volume

Volume of cookies is defined as the area of the cookies multiplied by its thickness.

$$\text{Volume (cm}^3\text{)} = \frac{3.14\ HD^2}{4}$$

where H = Thickness of cookie (cm), and D = Diameter of cookie (cm)

Density

After calculating the volume of cookies, density of them was obtained by ratio of mass to volume.

$$\text{Density (gcm}^{-3}\text{)} = \frac{\text{Mass of cookie (g)}}{\text{Volume of cookie (cm}^3\text{)}}$$

Spread ratio

The spread ratio was determined by using this formula.

$$\text{Spread ratio} = \frac{\text{Diameter of cookie}}{\text{Thickness of cookie}}$$

2.6 Sensory analysis of wheat – sweet potato flour composite cookies

The sensory attributes, including texture, colour, taste, mouth-feel and overall acceptability were evaluated by a trained twenty-member panel. Ranking test was used to evaluate the perceptible differences in intensity of an attribute among samples. Samples were presented in identical disposable plastic dishes, coded with 3 - digit random numbers. Each sample was given a different code number. All the samples were simultaneously presented to each panelist in a balanced or random order. Trained panelists are asked to rank the coded samples for the intensity of a specific characteristic, by ordering the samples from the most intense to the least intense. The panelists were allowed to re-evaluate the samples necessary to make the required comparisons among them.

2.7 Microbial examination

Potato Dextro Agar (PDA) preparation was carried out without any external contamination. Total plate count was taken as described below.

Peeled potato was cut into small pieces and added in 250 ml of distilled water and boiled. Weighed agar was boiled with 250 ml of distilled water until agar dissolve and placed in a 1000 ml of flask. Then required amount of sucrose and potato extraction were added into the flask and stirred. Then conical flask containing media was plugged with a cotton wool and wrapped aluminum foil. Then it was put into the autoclave at 121^{o}C, 15psi for 20 minutes and the media was allowed to cool. Petri dishes, forceps and needles were kept in the oven at 180^{o}C for one hour and allowed to cool. All the equipment were sterilized by 70% of alcohol. Then it was poured into petri dishes and they were kept in lamina flow until solidify. Different treatment samples were placed in agar plate. Then petri dishes were covered and labeled. The plates were observed after 4 days for plate count.

2.8 Shelf life evaluation

The shelf life of cookies was assessed based on the nutritional and sensory qualities. The cookies were organoleptically examined once in two weeks.

3 Results and Discussion

3.1 Nutritional composition of the freshly made sweet potato flour

Nutritional composition of the freshly prepared sweet potato flour is presented in Table 1. The results of nutritional composition of sweet potato flour are closely related with the results obtained by Sukhcharn *et al.* (2008). The moisture content of sweet potato flour was 8.1%. Sweet potato flour had fiber content 9.4%. This high fiber increases the utility of sweet potato flour in various food products and also had lesser extent of protein content (2.3%) compared to the wheat flour (12.6%). Most non wheat flours have less protein but higher carbohydrate content than wheat flour (Tindall 1968, Okorie and Onyeneke 2012).

Table 1. Nutritional composition of the freshly made sweet potato flour (the values are means of four replicates ± standard error).

Constituents	Content (%)
Moisture	8.10 ± 0.15
Ash	3.60 ± 0.15
Fat	0.52 ± 0.01
Fiber	9.40 ± 0.16
Protein	2.30 ± 0.20
Total sugar	11.20 ± 0.17
Reducing sugar	6.30 ± 0.22
Total soluble carbohydrate	85.48 ± 0.41

The high level of carbohydrates is desirable in baked products, because on heating, starch granules in the presence of water swells and forms a gel which is important for the characteristic textures and structures of baked goods (Amendole 1972; Okorie and Onyeneke 2012). Sweet potato flour was produced from white flesh sweet potatoes and was dull white in colour, had a somewhat sweet flavour. Greater nutritive value is achieved due to the fact that as greater part of water content is removed, while the carbohydrates, pectin, proteins, oils and mineral salts are concentrated in the tissue of dried food products.

3.2 Physical parameters of developed wheat – sweet potato cookies

The physical parametric analysis of the cookies revealed that, there was a significant differences between the treatments as the level of sweet potato flour was increased (0-100%) in respect of diameter, thickness, volume,

density and spread ratio of cookies at the 5% level of significance according to ANOVA.

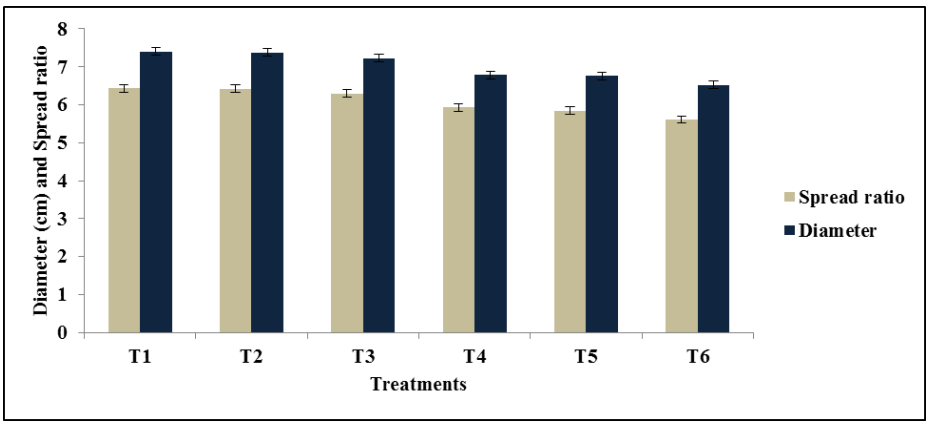

Fig. 1. Diameter and Spread ratio of different combination of wheat – sweet potato flour cookies (the values are means of four replicates; the vertical bars indicate the standard errors).

Diameter

There was a significant decrease in the diameter of control treatment (T_1) and other different treatments (T_2, T_3, T_4, T_5, T_6) after incorporating cookies with sweet potato flour. According to DMRT, control treatment which containing 100% wheat flour has the highest mean value (7.4 cm) followed by 20% sweet potato flour added cookie and 100% sweet potato cookie has the least mean value. Even though, there are no significant difference between control treatment and sweet potato flour added cookies up to 40%. Diameter and spread ratio of different combination of wheat – sweet potato flour cookies are shown in Figure 1.

Thickness

According to DMRT, control treatment which containing 100% wheat flour has the highest mean value (0.969 cm) followed by 20% sweet potato flour added cookie and 100% sweet potato cookie has the least mean value. The result showed that increase in level of sweet potato flour resulted in linear decrease of thickness and diameter of cookie. This might be due to the higher water holding capacity of sweet potato flour. Mean values of thickness,

volume and density of different combination of wheat – sweet potato flour cookies according to DMRT are shown in Table 2.

Volume

There was a significant decrease in volume of control treatment (T_1) and other different treatments (T_2, T_3, T_4, T_5, T_6) after incorporating cookies with sweet potato flour. According to DMRT, control treatment containing 100% wheat flour has the highest mean value and 100% sweet potato cookie has the least mean value.

Table 2. Thickness, volume and density of different combination of wheat – sweet potato flour cookies (means of four replicates ± standard error; the means with shared letters are not significantly different from each other at 5% level based on DMRT)

Treatments	Thickness (cm)	Volume (cm^3)	Density (gcm^{-3})
T_1	0.969 ± 0.003^{a}	41.66 ± 0.84^{a}	0.474 ± 0.009^{c}
T_2	0.949 ± 0.006^{b}	40.52 ± 0.91^{ab}	0.487 ± 0.011^{c}
T_3	0.931 ± 0.003^{c}	38.87 ± 0.82^{b}	0.508 ± 0.011^{c}
T_4	0.930 ± 0.002^{c}	34.33 ± 0.41^{c}	0.575 ± 0.007^{b}
T_5	0.920 ± 0.005^{cd}	32.99 ± 0.42^{c}	0.598 ± 0.007^{b}
T_6	0.910 ± 0.002^{d}	30.41 ± 1.21^{d}	0.652 ± 0.027^{a}

Density

The densities of the cookies gradually increase (0.474 - 0.652 gcm^{-3}) due to marginal increase of sweet potato flour. According to DMRT, there was no significant difference between control treatment and sweet potato flour added cookies up to 40% (T_2 and T_3). The volume of sweet potato cookies decreased linearly whereas, density increased in the similar manner. This may be due to higher fiber content in the sweet potato flour.

Spread ratio

There was a significant decrease in the spreading factor of control treatment (T_1) and different treatments (T_2, T_3, T_4, T_5, T_6) after incorporating cookies with sweet potato flour. According to DMRT, control treatment which containing 100% wheat flour has the highest mean value followed by 20% sweet potato flour added cookie and 100% sweet potato cookie has the least mean value. Even though, there was no significant difference between control treatment and sweet potato flour added cookies up to 40%. The differences in

spread factors of cookies containing different proportion of sweet potato flour may be attributed to the differences in swelling patterns and rheological properties. The results may be due to the higher fiber content, solid matter content and also high water holding capacity of the sweet potato flour.

3.3 Organoleptic evaluation of freshly made wheat – sweet potato flour composite cookies

The sensory evaluation of the cookies revealed that there were significant differences between the treatments as the level of sweet potato flour increased from 0 to100% for texture, mouth-feel, taste, colour and overall acceptability at the 5% level of significance according to ANOVA. Mean values of treatments according to Tukey's Studentized Range (HSD) test are shown in Table 3. The results of the sensory attributes of wheat and sweet potato flour blend cookies such as texture, colour, taste and overall acceptability have deviated pattern of scores and also score of mouth feel attribute have similar way of pattern compared with the results obtained by Sukhcharn *et al.* (2008). These different directions of score patterns may be due to the different rates of preference and acceptable values of panels and quality of finished cookies that were studied.

Texture

Texture is one of the most important parameters connected to product quality. It is defined as the sensory manifestation of the structure of food and the manner in which that structure reacts to the applied force (Jean-Xavier and Rossella, 1996). Texture analysis involves measuring the properties related to how a food feels in our mouth (initial bite). According to DMRT, there was no significant difference between the control treatment and series of 20 - 60% sweet potato flour added cookies (T_2, T_3, and T_4). The control treatment and T_3 have the highest mean value and T6 has the least mean value.

Mouth-feel

Mouth-feel analysis involves measuring the properties of cookies such as crunchy, granular, flaky and teeth clogging. Mouth-feel attributes of cookies decreased from 4.50 to 3.30 with increasing in the substitution of sweet potato flour. According to DMRT, there were no significant differences between control treatment (T1) and sweet potato flour added cookies up to 60%. The control treatment (T1) has the highest mean value and T6 has the least mean value.

Table 3. Mean values of organoleptic attributes of cookies incorporated with sweet potato flour at different levels (the values are means of 20 replicates ± standard error)

Treatments	Texture	Mouth-feel	Taste	Colour	Overall acceptability
T_1	4.85 ± 0.05^{a}	4.50 ± 0.11^{a}	4.25 ± 0.27^{abc}	4.60 ± 0.11^{ab}	4.75 ± 0.08^{a}
T_2	4.55 ± 0.11^{a}	4.45 ± 0.11^{a}	4.30 ± 0.15^{abc}	4.65 ± 0.10^{a}	4.45 ± 0.11^{a}
T_3	4.85 ± 0.05^{a}	4.30 ± 0.12^{a}	4.50 ± 0.11^{ab}	4.80 ± 0.07^{a}	4.70 ± 0.09^{a}
T_4	4.45 ± 0.11^{a}	4.20 ± 0.13^{ab}	4.80 ± 0.07^{a}	4.75 ± 0.08^{a}	4.60 ± 0.11^{a}
T_5	3.95 ± 0.15^{b}	3.60 ± 0.16^{bc}	3.95 ± 0.14^{bc}	4.15 ± 0.12^{bc}	3.75 ± 0.17^{b}
T_6	3.55 ± 0.15^{b}	3.30 ± 0.22^{c}	3.60 ± 0.15^{c}	3.70 ± 0.20^{c}	3.40 ± 0.12^{b}

*The means with the shared letters are not significantly different from each other at 5% level based on Tukey's Studentized Range (HSD) Test.
*The sensory attributes were analyzed in ranking test with the values from 1 to 4.9.

Taste

Cookie containing 60% sweet potato flour had sweet taste and 100% sweet potato flour contained cookie had either caramel or burnt taste. This might be due to the caramelization of free sugar in sweet potato during baking (Sukhcharn, et al. 2008). According to DMRT, T_4 as highest mean value and 100% sweet potato flour added cookie has the least mean value.

Colour

The quality of food is generally based on colour, flavour, texture and nutritive value. An attractive colour leads to the food to make good demand. The colour of cookie changed from light brown to dark brown. The darker colour may be due to Maillard reaction between reducing sugar and protein (Raidi and Klevin 1983; Dhingra and Jood 2000). According to DMRT, T_3 has highest mean value and 100% sweet potato flour added cookie T_6 has the least mean value.

Overall acceptability

Overall acceptability includes many implications, which is the important parameter in sensory estimation. There were no significant differences between control treatment and 20 – 60% sweet potato flour added cookies (T_2, T_3 and T_4). The 40% sweet potato flour added cookie (T_3) has highest mean value and 100% sweet potato flour added cookie (T_6) has the lowest mean value.

3.4 Sensory analysis of wheat – sweet potato cookies following storage

Organoleptic characteristics of the cookies were changed slightly following the storage period. This may be due to the non – enzymatic browning reaction (Maillard reaction) and fat oxidation.

Table 4. Mean values of Sensory attributes of stored wheat – sweet potato cookies (the values are means of 20 replicates ± standard error).

Treatments	Texture	Mouth-feel	Taste	Colour	Overall acceptability
T_2	4.52 ± 0.11^{b}	4.40 ± 0.12^{a}	4.30 ± 0.15^{b}	4.65 ± 0.10^{a}	4.35 ± 0.11^{a}
T_3	4.82 ± 0.05^{a}	4.25 ± 0.15^{a}	4.50 ± 0.11^{ab}	4.80 ± 0.07^{a}	4.60 ± 0.11^{a}
T_4	4.42 ± 0.11^{b}	4.16 ± 0.15^{a}	4.80 ± 0.07^{a}	4.75 ± 0.08^{a}	4.50 ± 0.11^{a}

The means with the shared letters are not significantly different from each other at 5% level based on Tukey's Studentized Range (HSD) Test.
The sensory attributes were analyzed in ranking test with the values from 1 to 4.9.

The 40% sweet potato flour added cookie (T3) has the best shelf life in nutritional and organoleptical point of view compared to other combinations of wheat and sweet potato flour. Mean values of sensory attributes of stored wheat – sweet potato cookies are shown in Table 04. From the overall acceptance rating, the 40% sweet potato flour added cookie has the highest mean value and no remarkable changes in organoleptic characters were observed up to three months of storage in ambient condition of average temperature 300C and relative humidity of 75 – 80%, indicate that the 40% sweet potato flour added cookies could be preserved up to three months.

4 Conclusions

The finding of the present research revealed that sweet potato contains considerable amount of protein, although rich in dietary fiber content and carbohydrate, so that a successful combination with wheat flour for cookie production would be nutritionally advantageous and also sweet potato flour with wheat flour has significant effect on the physical properties of the flour blends. Sweet potato flour (40%) incorporated cookies have highly acceptable functional and organoleptic quality characters compared to other combinations. The outcome of the present research can be used as valuable information for the development of high fiber low gluten sweet crunchy cookies. The results obtained could be very valuable in decision making for industries that want to take nutritional advantage of sweet potato flour as alternative or supplement to cereal flours.

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