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Determination of physical and functional properties of orange fleshed sweet potato (*Ipomea batatas* L.) flour

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Abstract
Vitamin A deficiency is caused by a habitual diet that provides too little bio available vitamin A to meet physiologic needs. Apart from cheap source of energy, Orange fleshed sweet potato is an excellent source of the β-carotene. This crop is also gaining importance as the cheapest source of antioxidant having several physiological attributes like anti-oxidation, anti-cancer and may help in protection against liver injury and coronary heart disease. Fresh tubers are bulky and perishable, which can be processed into flour and can be used in manufacturing of various value added food products.

Keywords: Orange fleshed sweet potato, bulk density

1. Introduction

Orange fleshed sweet potato is an improved breed of sweet potato, now emerging as an important member of the tropical tuber crops. It is cultivated in tropical and semi-tropical regions of the world for food and source of income, especially among the rural dwellers (Padmaja, 2009; Mitra, 2012 and Adebisi *et al.* 2015) [39, 30, 3]. Orange fleshed sweet potato (OFSP) is also a good source of energy, easy to propagate vegetatively in marginal fields (Hagenimana *et al.* 2001) [21]. It has short maturity period compared to other root and tuber crops. The edible tuberous root is either long and tapered, ovoid or round with a skin colour ranging from white, brown or purple and the flesh colour ranging from pale cream, orange or purple. Owing to its rich β-carotene, the OFSP is gaining importance, as the cheapest source of antioxidant, having several physiological attributes like anti-oxidation, anti-cancer that may help in protecting against liver injury and coronary heart disease (Grace *et al*. 2015) [20].

In developing countries like India, sweet potato tubers are mostly consumed in boiled, steamed or fried forms at the household level. Fresh tubers are bulky and perishable which limits its utilization. These tubers can be processed into flour, a shelf stable product, which remains in good condition for a long time. The conversion of sweet potato into flour is expected to tackle transportation and storage problems and also encourage production and availability of sweet potato flour all the year round. Sweet potato flour has a high potential for manufacturing of a variety of value added products such as biscuits, bread, cakes, cookies, doughnuts, instant porridge, macaroni products, sauces and different brewing adjuncts (Van Hal, 2000 and Mais and Brennan, 2008) [46, 27].

2. Materials and methods

2.1 Sweet potato sample

Orange Fleshed Sweet Potato (OFSP) of Gauri variety was procured from horticultural farm of Rajasthan College of Agriculture (RCA), Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur, Rajasthan in a single lot to avoid varietal difference.

2.2 Preparation of flour

The fresh tuber were sorted and thoroughly washed, trimmed, peeled and sliced into thin slices of 0.5mm thickness with the help of stainless steel slicer, so that uniform drying occurs. The cut slices were soaked in 0.5 per cent potassium metabisulphite (KMS) solution for 15 minutes to prevent browning reactions. Thus, they were blanched for 3 minutes and dried overnight in hot air oven at 60 °C. The dried slices were ground in mixer grinder and sieved (70 mesh size) to prepare OFSP flour.

The prepared flour was packed in air tight container and stored at ambient temperature for further use. The main principal steps used for preparation of OFSP into flour are illustrated in Figure 1 and Plate 1

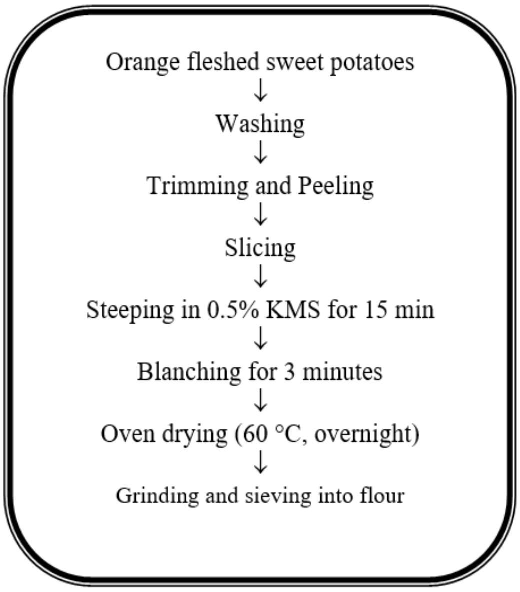

Fig 1: Flow Diagram of OFSP flour processing

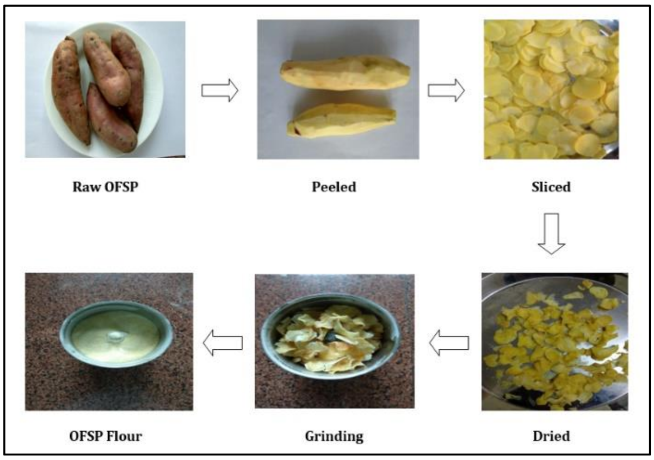

Plate 1: Processing and preparation of orange fleshed sweet potato flour

2.3 Physical properties: The analysis of physical properties of OFSP flour was carried out using standard procedures as described below

2.3.1 Flour Yield
Flour yield of OFSP was calculated as suggested by Samata, (2007) [42]. Hundred grams of OFSP tuber was considered for flour yield calculation. After the completion of preparation steps, the total OFSP flour obtained was weighted and expressed as percentage.

2.3.2 Bulk Density
Bulk density of OFSP flour was assessed using the methods suggested by Okaka and Potter (1977) [34]. Fifty gram of flour was placed in a 100ml graduated cylinder and packed by gentle tapping of measuring cylinder on the bench top 20 to 30 times from a height of 5 to 6cm. The bulk density of flour was expressed as weight per unit volume in gram per ml.

2.3.3. Solubility
Solubility of OFSP flour was estimated as described by Bishnoi and Khetrapal (1993) [15] with little modifications. One gram of OFSP flour was weighed into a centrifuge tube and 10 ml distilled water was added in it. The centrifuge tube along with sample was heated on water bath for 30 minutes at 60°C and constantly stirred with the help of glass rod. The tube containing the flour paste was centrifuged at 4000 rpm for 15min. After completion, the supernatant was decanted into a pre-weighed crucible and dried in oven to constant weight. The residue remaining in the tubes and crucible after drying were weighed. The difference in weight of crucible was used to calculate the water solubility and expressed in percentage.

$$\text{Solubility (\%)} = \frac{\text{Weight of crucible after drying} - \text{Weight of empty crucible}}{\text{Weight of sample}} \times 100$$

2.3.4 Swelling Capacity
Swelling capacity of OFSP flour was estimated as described by Bishnoi and Khetrapal (1993) [15] with little modifications. Swelling capacity was carried out by weighing three gram of flour sample into clean, dry graduated 50 ml measuring cylinders. The flour sample was gently leveled and the volume was noted before addition of 30ml distilled water. The cylinder was swirled manually and allowed to stand for 60 minutes while the change in volume was recorded. The swelling capacity of flour was calculated as difference in volume after and before soaking of sample in cylinder and was divided by initial weight of the sample.

$$\text{Swelling capacity} = \frac{\text{Volume after soaking (ml)} - \text{Volume before soaking (ml)}}{\text{Weight of sample (g)}} \times 100$$

2.3.5 Hydration Capacity
Hydration capacity of OFSP flour was estimated through the methods described by Bishnoi and Khetrapal (1993) [15]. Fifty gram of flour sample was taken into clean, dry beaker and 100ml water was added. The flour sample was gently stirred, covered with aluminum foil and kept overnight at room temperature. Next day superfluous water was removed with filter paper and the change in weight was recorded. The hydration capacity was calculated as difference in weight after and before soaking of flour and was divided by initial weight of sample.

$$\text{Hydration capacity} = \frac{\text{Weight after soaking (g)} - \text{Weight before soaking (g)}}{\text{Weight of Sample (g)}} \text{ x } 100$$

2.4 Functional Properties
2.4.1. Water Absorption Capacity (WAC)
Water absorption capacity of OFSP flour was determined using the method suggested by Sosulski *et al*. (1976) [44]. One gram of OFSP flour sample was mixed with 10 ml of distilled water. It was kept at ambient room temperature for 30 min and centrifuged at 2000 rpm for 30min. Excess water was decanted and flour sample was allowed to drain by inverting the tube over absorbent water. The water absorption capacity was expressed as per cent water absorbed per gram of the flour.

$$\text{WAC(\%)} = \frac{\text{Weight of sample after centrifugation(g)} - \text{weight of sample before centrifugation(g)}}{\text{Weight of sample (g)}} \text{ x } 100$$

2.4.2. Oil Absorption Capacity (OAC)
Oil absorption capacity was determined using the method suggested by Sosulski *et al*. (1976) [44]. One gram of OFSP flour sample was mixed with 10 ml of refined soyabean oil and kept at ambient temperature for 30min and centrifuged at 2,000 rpm for 30min. Excess oil was decanted and each sample was allowed to drain by inverting the tube over absorbent oil. The oil absorption capacity was expressed as per cent oil bound per gram of the flour.

$$\text{OAC (\%)} = \frac{\text{Weight of sample after centrifugation (g)} - \text{weight of sample before centrifugation (g)}}{\text{Weight of sample (g)}} \text{ x } 100$$

2.4.3. Least Gelatinization Concentration
The least gelatinization concentration of OFSP flour was determined using methods of Coffman and Garcia (1977) [17]. The flour dispersion of 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34 per cent (w/v) were prepared in 5ml distilled water and heated at 90°C for one hour in water bath. The content were cooled under tap water and kept for two hour at 10°C. The least gelation concentration was determined as that concentration when flour from inverted tube did not slip.

2.4.4. Foaming Capacity and Foaming Stability
Foaming capacity and foaming stability of OFSP flour were determined as described by Narayana and Narsingha Rao (1982) [32]. One gram of flour sample was added to 50ml distilled water at 30 °C in a graduated measuring cylinder. The suspension was mixed and shaken for five minutes to foam. The volume of foam after whipping for 30 sec and was expressed as foaming capacity. The volume of foam was recorded one hour after whipping to determine foaming stability as percent of the initial foam volume.

$$\text{Foaming Capacity (\%)} = \frac{\text{Volume of Foam (AW)} - \text{Volume of Foam (BW)}}{\text{Volume of foam (BW)}} \text{ X } 100$$

Where, AW= After whipping
BW=Before whipping

$$\text{Foaming Stability} = \frac{\text{Foam volume after one hour of whipping}}{\text{Foam volume after whipping}} \text{ x } 100$$

2.5 Data Analysis
All experiment was performed in triplicate. Results were expressed as mean, standard deviation and percentage.

3. Results and Discussion
3.1 Physical Properties
The results of physical properties of OFSP flour (Gauri) have been presented in Table 1. The yields of OFSP flour were 18.75± 0.25 per cent after processing of raw tuber. The results are in line with Atif *et al.* (2018) [12], who reported the yield of flour ranged from 17.16 to 21.65 per cent and significantly varied among the varieties of OFSP and different blanching treatments. Finding of Rodrigues *et al.* (2016) [41] were observed to be higher, as investigators reported the 23.96 per cent flour yield for OFSP. Omodamiro *et al.* (2013) [37] documented flour yield of 21.5 per cent in some varieties of OFSP tubers, which is slightly higher than the result of the present investigation. The major reason for the difference in the flour yield of OFSP might be owing to the difference in cultivars, climatic conditions, variation in moisture and dry matter content as well as trimming and peeling losses during processing.

Table 1: Physical properties of OFSP flour (per 100g of dry wt. basis)

Sl. No	Physical Properties	Mean□SD
1	**Flour yield (%)**	18.75±0.25
2	Bulk Density (g/ml)	0.73±0.01
3	Solubility (%)	14.90±0.14
4	Swelling capacity (ml/g)	0.83±0.02
5	Hydration capacity (%)	67.83±0.76

All the values are (Mean±SD) of three observations

Physical properties of flour denote the characteristics like bulk density, solubility, swelling capacity and hydration capacity. These characteristics govern the behavior of nutrients during preparation; processing and storage of foods as they affect quality and consumer acceptability of products. These are very useful parameters in making compatibility of flour for a particular product and reduce processing loss. Thus, physical property helps in improvement of the overall quality of the food product.

Bulk density is an indication of porosity of products which influences package design. The bulk density is influenced by the particle size, structure of the starch polymers. A loose structure of starch polymers could result a low bulk density (Plaami, 1997) [40]. It is also affected by moisture content and distribution of particle size in flour. The bulk density of OFSP flour was 0.73 ± 0.01g per ml. Tiruneh *et al.* (2018) [45] also reported the bulk density was 0.74g per ml and 0.62g per ml for the flour obtained from two cultivars of OFSP respectively. A high bulk density of the flour and starches indicates that they would serve as a good thickener in food products development (Adebowale *et al.* 2005) [4] while a low bulk density of flour and starch will be suitable for the formation of high nutrients dense weaning foods (Mepba *et al.* 2007) [29]. It revealed that OFSP flour has high bulk density indicates the heaviness and its suitability for production of confectioneries.

The solubility of OFSP flour was to be found 14.90 ± 0.14 per cent (Table 1). The results were in line with the finding of Abegunde *et al.* (2013) [2] who reported water solubility ranged from 8.56 to 19.97 percent in starches extracted from different varieties of sweet potato. Yadav *et al.* (2006) [47] documented the water solubility varied from 20 to 30 per cent for sweet potato flour obtained by different processing methods. Ahmed *et al.* (2010) [7] reported the water solubility ranged from 22.40 to 27.23 per cent of the sweet potato flours prepared by drying of tubers at different temperatures. The variation in water solubility of OFSP flour can be explained by the different processing method of flour production and even the presence of the wall materials in tubers.

The swelling capacity of OFSP flour was observed 0.83±0.02ml per gram. Finding of Ahmed *et al.* (2010) [7] were observed to be higher as investigator reported the swelling capacity of flour ranged from 1.92 to 2.56ml per g in different cultivars of sweet potato. Swelling capacity of flour is an important parameter as it determines the consistency of the food. Swelling capacity is related to associative binding within the starch granules, strength and character of the micelle network as related with amylose content. A high amylose content of flour produces low swelling capacity (Adebowale *et al.* 2005) [4]. Swelling capacity also expresses the expansion of starch accompanying the spontaneous uptake of a solvent, while solubility is the amount of water soluble solids present in per unit weight of the food sample (Adepeju *et al.* 2014) [5]. Swelling can causes changes in the hydrodynamic properties of the food, thus impacting certain characteristics such as body thickening and increased viscosity of foods (Kinsella, 1976) [25]. The hydration capacity of OFSP flour was to be found 67.83± 0.76ml per gram. According to Berton *et al.* (2002) [14] hydration capacity is very crucial in the food industries, because it affects the functional properties and the quality of bakery products (bread, cookies, etc).

3.2 Functional properties

Functional properties of flour can contribute a vital role in determining the competitiveness of nutrients, ingredients or products in the market, as they can impact the sensory, physical and chemical properties of food products (Tiruneh *et al.* 2018) [45]. These properties are very important to determine for its usefulness in food applications.

Some representative attributes such as water absorption capacity, oil absorption capacity, least gelatinization capacity, foaming capacity and foaming stability were analyzed to evaluate the functional properties of OFSP flour. The values of functional properties of OFSP flour are shown in Table 2.

Table 2: Functional properties of OFSP flour (per 100g of dry wt. basis)

Sl. No.	Functional Properties	Mean □□SD
1	Water absorption capacity (%)	215.72±2.24
2	Oil absorption capacity (%)	103.53±2.19
3	Least gelatinization capacity (%)	8.0±0.01
4	Foaming capacity (%)	56±0.26
5	Foaming stability (%)	12.5±0.50

All the values are (Mean□SD) of three observations

The water absorption capacity is the ability of flour or food to retain water against gravity. It includes bound water, hydrodynamic water and physically entrapped water present in foods (Moure *et al.* 2006) [31]. Water absorption capacity helps to determine the flour ability to absorb water and swell for improved consistency in food. It is desirable in food systems to improve yield and consistency and also provide shape to food. Water absorption capacity is found to be useful in bulking and thickening agent of products as well as also in baking application (Niba *et al.* 2001) [33]. The water absorption capacity of OFSP flour to be found 215.72±2.24 per cent, which was similar to the reported value ranged from 140 to 280 per cent by Olatunde *et al.* (2015) [35] of flours prepared from different variety of sweet potato. Tiruneh *et al.* (2018) [45] also reported the water absorption capacity of 253 and 212 per cent respectively for two genotypes of OFSP, which is in accordance with present study.

Oil absorption capacity is important as oil acts as flavour retainer and increases the mouth feel of foods. It also improves the palatability and extends the shelf life of baked products, where fat absorptions are desirable (Aremu *et al.* 2007). It is apparent from the result present in Table 2 that the oil absorption capacity of OFSP flour was found to be 103.53±2.19 per cent. The oil absorption capacity of OFSP flour was similar to refined wheat flour (Baljeet *et al.* 2010). A higher oil absorption capacity of OFSP flour not only improves the mouth feel but also retains the flavour of foods. The presence of protein in food exposes more non polar amino acids to the fat and enhances hydro-phobicity as a result of which the flour absorbs more oil (Oluwalana *et al.* 2011).

Least gelatinization capacity measures the minimum amount of flour required to form a gel in a measured volume of water. It varies from flour to flour depending on the relative ratios of their structural constituents like protein, carbohydrates, and lipids (Abbey and Ibeh, 1988) [1]. Gelation is not only depend on protein and water content but also on existence of other extraneous chemicals constituents, sugars, salts and other small molecules (Correia *et al.* 2009) [18]. In the present study, the least gelatinization capacity of OFSP flour was found 8.0±0.01 per cent (Table 2). Haile *et al.* (2015) [22] documented least gelation capacity ranged from 7.0 to 20.5 per cent for flours obtained from different root and tuber crops. The variation in least gelatinization capacity was mainly attributed to varietal difference, pre-treatment, blanching time and temperature and different drying method used for making flour. The variation in the least gelatinization capacity of OFSP flours was attributed to the relative ratio of protein, carbohydrates and lipids that make up the flours and interaction between such components (Sathe *et al*. 1982) [43].

Foams are a colloidal of many gas bubbles trapped in a liquid or solid phase are surrounded by thin liquid films. Foaming capacity is used to determine the ability of the flour to foam which is dependent on the presence of the flexible protein molecules and it decreases the surface tension of water (Alam *et al.* 2014) [10]. Kinsella (1979) [26] documented that it is a capacity of protein to form sTable foams with gas by forming impervious protein films, are an important property in cakes, soufflés, whipped toppings, fudges etc. The foaming capacity and foaming stability of flour helps to improve the texture and uniformity aspect of the food (Akubor, 2007) [9].

The foaming capacity of OFSP flour was observed 5.6±0.26 per cent. The result is in agreement with Boni *et al.* (2018), who reported the foaming capacities of flour were ranged from 3.5 to 3.13 per cent for different cultivars of sweet potato.

The foam stability refers to the ability of protein to stabilize against gravitational and mechanical stresses (Fennama, 1996) [19]. The foaming stability of OFSP flour was observed 12.5±0.50 per cent as depicted in Table 2. According to Chandra *et al.* (2015) [16] the foaming stability varied from 1.94 to 13.40 per cent of composite flours prepared with different incorporation percent of sweet potato flour. Jitngarmkusol *et al.* (2008) [24] reported an inverse relationship between foaming capacity and foaming stability of flour. Yasumatsu *et al.* (1972) [48] stated that the foaming capacity and its stability of flour depend on the pH, viscosity, proteins and processing methods.

Thus, the functional attributes of sweet potato flour may vary considerably due to the varietal differences (Osundahunsi *et al.* 2003 and Aina *et al.* 2009) [38, 8], processing steps like peeling (Van Hal, 2000) [46] as well as different processing methods like blanching (Jangchud *et al.* 2003) [23], parboiling (Osundahunsi *et al.* 2003) [38], drying techniques (Yadav *et al.*2006) [47], drying temperatures (Maruf *et al.* 2010) [28] and environmental condition during the experiment.

4. Conclusion

Thus, the results revealed that the OFSP flour has appealing bulk density, water absorption capacity, oil absorption capacity, solubility and swelling capacity, which suggests that incorporation of OFSP flour, has a great technological quality and viability in several kinds of food products.

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