International Food Research Journal 23(5): 2071-2078 (2016)
Journal homepage: *http://www.ifrj.upm.edu.my*

Determination of physico-chemical composition, nutritional facts and technological quality of organic orange and purple-fleshed sweet potatoes and its flours

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Article history

Received: 8 August 2015
Received in revised form: 29 December 2015
Accepted: 2 February 2016

Keywords

Chemical composition
Organic flours
Sweet potatoes

Abstract

This work aimed to evaluate the chemical composition of organic orange and purple-fleshed sweet potatoes (OFSP and PFSP, respectively) and its flours and to determinate the technological quality and the nutritional facts of these organic flours. Fresh samples and flours presented proximal composition and starch, crude fiber, acidity contents and pH values in agreement with previous studies. The starch contents ranged from 65.41 to 103.7% for fresh OFSP and PFSP, respectively. OFSP and PFSP flours presented 90.13 and 88.15% of total carbohydrates, respectively. Both flours presented fiber contents of 2.57%. The OFSP flour presented 191 kcal, and its vitamin A content represents 85.3% of daily values. It was also found that the organic flours presented interesting technological properties, allowing to be used as raw materials in the preparation of food products.

Introduction

Sweet potato was brought to Europe by Columbus and subsequently introduced to Africa and Asia by the Portuguese and Spanish traders (Salawu and Mukhtar, 2008). The crop is highly adaptable and tolerates high temperatures, low fertility soil and drought (Laurie *et al.*, 2013). A large percentage of the sweet potatoes produced in China is used for production of starch and related products (Mei *et al.*, 2010). This tuber is a versatile crop with multiple uses, and could be used as a substitute for rice and corn, besides being a potential source of raw materials, and has been processed as feeds, flour, starch, and pectin (Ramesh *et al.*, 2006).

Traditionally, sweet potato varieties produced and sold in southern Africa have a pale coloured flesh, but new biofortified orange flesh sweet potato varieties (OFSP) have been introduced. They present high concentrations of β-carotene (provitamin A) (Oirschot *et al.*, 2003; Oki *et al.*, 2006; Tomlins *et al.*, 2012). Orange-fleshed sweet potato (OFSP) is among the biofortified staples bred for high provitamin A potential (CIP, 2006). Burri (2011) reports the importance of sweet potato, as an intervention food to prevent vitamin A deficiency. In contrast to the pale-fleshed varieties that have been grown by farmers, these new varieties with high β-carotene contents, could benefit an estimated 50 million children under age 6 who are currently at risk (Tomlins *et al.*, 2012). Furthermore, the high content of carotenoids provides antioxidants properties (Oki *et al.*, 2006).

OFSP flours are also provitamin A sources, and presents important effects to human health (Alves *et al.*, 2012). Rodrigues *et al.* (2013) evaluated the effects of OFSP processing into flours, showing a negative impact on total carotenoids and vitamin A. However, even with losses after processing, flour can be considered sources of these compounds.

Purple-fleshed sweet potato (PFSP) is a functional food rich in anthocyanins that has been reported to possess unique color, nutrition and disease-preventive properties (Goda *et al.*, 1997; Tian *et al.*, 2005; Hwang *et al.*, 2011c). In the past few years, sweet potato cultivars with deep purple flesh were developed in Japan, Korea, New Zealand, and other countries to meet a growing demand in the health food markets (Lee *et al.*, 2000; Phillpot *et al.*, 2003). It has been reported that the concentration of anthocyanins in PFSP is similar to the highest anthocyanin production crops, such as blueberries, blackberries, cranberries or grapes (Bridgers *et al.*, 2010). Anthocyanins from PFSP have been shown to exhibit strong radical scavenging and antimutagenic activity, significantly reduce high blood pressure, and have anti-inflammatory, antimicrobial, and ultraviolet

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protection effects (Oki *et al*., 2002; Suda *et al.*, 2003; Teow *et al.*, 2007).

It's characteristic to create food products for normal and specialized nutrition on the basis of raw material obtained from various cultivated and wild-growing forms of plants (Alexeev *et al*., 2015). According to Ladjal Ettoume and Chibane (2015), the use of legume flours could serve as cheap and alternate source of nutrients, and are useful for inclusion in the human diet for their beneficial health effects and to improve overall nutritional status of functional food. Therefore, in this study we investigate the physico-chemical characteristics of organic OFSP and PFSP and its flours. Furthermore, we evaluated the nutritional facts and the technological quality of these co-products.

Materials and Methods

Material

Orange and purple-fleshed organic sweet potatoes were obtained from Embrapa Agrobiologia-Seropédica/ Rio de Janeiro, Brazil, in july and august 2014, respectively.

Sample preparation

Sweet potatoes were washed, sanitized, peeled and comminuted in multiprocessor and stored in polyethylene bags at -18˚C for 2 days until processing. Flours were obtained as follows: the samples were washed, sanitized, peeled and sliced manually. Thus, they were blanched at 100˚C for 20 minutes and hot-air dried at 65˚C for 24 h. After these steps, the dried samples were ground and stored under refrigeration at -18˚C.

Chemical and physical composition

Moisture, protein, fat and ash contents and pH were determined according to the methodology described by Association of Official Analytical Chemists (AOAC, 1997) and expressed in g per 100 g of dry weight (DW). Total carbohydrates content was determined by difference, according to AOAC (1990), and expressed by Equation 1:

Total carbohydrates (%)= 100- (L+P+F+A) Equation (1)

Where: L=lipids (%); P=proteins (%); F=crude fiber (%); A=ash (%).

Starch contents were determined according to AACC (1995). Crude fiber was determined by gravimetric method described by Kamer and Ginkel (1952). Starch and crude fiber were expressed in grams per 100 g of dry weight. Acidity content followed as described by Adolfo Lutz Institute (2009), and expressed in miligrams of NaOH per 100 g of dry weight (DW).

Determination of technological quality of organic flours

The yield of each flour was evaluated according to Vieira and Silva (2010).The water absorption (WAI) and water solubility (WSI) indexes were determined according to Anderson *et al.* (1969). Fat absorption index (FAI) was taken according to the method of Dench *et al.* (1981); the volume swelling power (SP), followed by the methodology reported by Robertson *et al*. (2000).

Nutritional facts of organic flours

Nutritional information of organic flours were determined as preconized by Resolution RDC 360/2003 (Brasil, 2003a). The portion and home measure were determined according to Resolution RDC 359/2003 (Brasil, 2003b).

Results and Discussion

Physico-chemical composition

The chemical composition of organic orange and purple-fleshed sweet potatoes (OFSP and PFSP) and its flours are presented in Table 1 and Table 2, respectively. Generally, the proximate composition of fresh sweet potato tubers and flours in this study are in agreement with the values reported by Aina *et al.* (2009). Moisture content of the fresh tubers ranged from 69.4 to 73%, and 6.9 to 10.97% in flours. Ash content depends on the type of food and determination method employed (Cecchi, 2003). Ash contents of fresh samples varied between 2.04% (OFSP) and 3.80% (PFSP), and for flour, these values ranged from 2.11% (OFSP) and 3.07% (PFSP). OFSP flours showed higher protein content (4.8%) when compared to fresh samples (3.69%), as PFSP flours, which presented 5.82% of protein while fresh PFSP presented 5.7% of proteins. Sibt-e-Abbas *et al.* (2015) reported higher crude protein contents (26.17 and 27.42%) for peanut flours, wich can supplement bakery products. Bartova and Bárta (2009) found that potatoes are not considered a rich source of protein. However, presents a kind of protein with high nutritional and biological potential. According to Garcia (2013), the increase in average mass and the accumulation of starch may contribute to a lower protein content during tubers generation. According to Aina *et al.* (2009), sweet potato-like other roots and tubers is known for its low fat contents. Fresh samples of OFSP and PFSP presented the same

Table 1. Chemical composition of orange-fleshed sweet potatoes (OFSP) and its flours

Analysis	Fresh sample	Flour
Moisture (g.100 g^{-1})	69.42 ± 0.16	10.97 ± 0.95
Ash (g.100 g^{-1})	2.04 ± 0.08	2.11 ± 0.12
Protein (g.100 g^{-1})	3.69 ± 0.44	4.80 ± 0.24
Fats (g.100 g^{-1})	0.42 ± 0.04	0.39 ± 0.03
Starch (g.100 g^{-1})	65.41 ± 3.17	33.66 ± 3.76
Crude fiber (g.100 g^{-1})	3,68 ± 0.25	2.57 ± 0.14
Total carbohydrates (g.100 g^{-1})	90.17	90.13
pH	6.55 ± 0.01	6.52 ± 0.03
Acidity (mL NaOH.100 g^{-1})	1.08 ± 0.01	0.91 ± 0.01

*Results are expressed in dry basis (except moisture values).

Table 2. Chemical composition of purple-fleshed sweet potatoes (PFSP) and its flours

Analysis	Fresh sample	Flour
Moisture (g.100 g^{-1})	73 ± 1.6	6.91 ± 0.71
Ash (g.100 g^{-1})	3.80 ± 0.49	3.07 ± 0.69
Protein (g.100 g^{-1})	5.70 ± 0.79	5.82 ± 1.43
Fats (g.100 g^{-1})	0.42 ± 0.04	0.39 ± 0.03
Starch (g.100 g^{-1})	103.7 ± 0.17	92.67 ± 1.94
Crude fiber (g.100 g^{-1})	4.28 ± 0.07	2.57 ± 0.14
Total carbohydrates (g.100 g^{-1})	85.8	88.15
pH	6.55 ± 0.01	6.58 ± 0.02
Acidity (mL NaOH.100 g^{-1})	0.90 ± 0.02	0.87 ± 0.03

*Results are expressed in dry basis (except moisture values).

content (0.42%) of fat. Flours shower lower fat content than others (Ahmed *et al*., 2010; Kidane *et al.*, 2013). Jangchud *et al*. (2003) reported fat content of 0.6% for OFSP flours, for example. OFSP and PFSP flours showed higher fat content when compared to cassava flours (0.17 to 0.20%) (Chisté *et al*., 2007).

Starch content obtained in present study ranged from 65.41 to 103.7% (fresh samples of OFSP and PFSP, respectively) and 33.66 to 92.67% (OFSP and PFSP flours, respectively). Results showed that PFSP presents higher starch contents when compared to OFSP. These ones are higher than the values reported by Andrade Junior *et al.* (2012) for some cultivars of fresh sweet potatoes, of 23.9% (DW). Results showed that processing affected the starch content of fresh samples negatively, probably due to degradation of starch during the drying step, which resulted in lower starch content of flours. Abegunde *et al.* (2013) observed values of starch ranging from 91.9 to 95.6% (DW) for eleven cultivars of sweet potato. Chiwona-Karltun *et al.* (2015) evaluated processing effects on biochemical composition of cassava, and obtained starch contents between 53.12 and 76.34%. These authors showed that the different processing techniques had only minimal but significant effects on the starch and sugar content of the different cassava varieties.

Tables 1 and 2 shows the mean values of crude fiber contents of fresh samples which ranged from 3.68 to 4.28% (OFSP and PFSP, respectively). These results are higher than the mean value reported by Ravindran *et al.* (1995) for sixteen cultivars of sweet potatoes of 2.36% (DW) and the contents found by Aziz *et al.* (2013) for ten varieties of potatoes (2.40%, DW). On the other hand, the mean value of crude fiber of OFSP and PFSP organic flours is 2.57% (DW), suggested that these compounds decreased after processing, which is not in accordance with other studies (Li *et al*., 1995; Jangchud *et al*., 2003), in which crude fiber content increased after samples blanching and cooking.

Ribeiro *et al.* (2015) observed that cauliflower stalk flour and cauliflower leaf flour contained a high amount of crude fiber, ranging of 31.13 to 47.07%, respectively. These results are higher than fiber contents found in the present study. Although the information presented, fiber contents of OFSP and PFSP flours did not present a functional allegation, according to RDC° 18 (1999), which establishing basic guidelines for analysis and proof of properties functional and/or health in food labels. It is established that a portion of cereals and tubers flours (50 g or a quarter cup) needs to contain at least 3 g of dietary fibers to have functional allegation and health effects.

In this study, organic OFSP presented total carbohydrates content of 90.17 and 90.13% (for fresh samples and flours, respectively). Organic PFSP presented carbohydrates content of 85.8 and 88.15% (for fresh samples and flours, respectively) (DW). Fresh samples demonstrated higher carbohydrates content, compared to mean value reported by TACO (2011), of 28.2% for sweet potatoes. However, flours presented carbohydrates content similar to values found by Leonel *et al*. (1998) for sweet potato flours.

Fresh samples and flours presented pH values at the same range, from 6.55 to 6.58, showing that pH is not influenced by processing. Results are in agreement with other studies. Roesler *et al.* (2008) reported pH values ranging from 6.15 to 6.38 for different varieties of PFSP and from 6.12 to 6.51 for pink-fleshed sweet potatoes. Steed and Truong (2008) studied PFSP, obtaining pH values among 6.0. Leonel *et al.* (1998) have also reported pH value from 6.37 for sweet potatoes starchs. The acidity content

Table 3. Yield, WSI, WAI, FAI and SP determination of organic orange and purple-fleshed sweet potatoes (OFSP and PFSP) flours

	Yield (%)	WSI (%)	WAI (%)	FAI (%)	SP (mL. g^{-1})
OFSP	23.9±0.6	38.88±0.46	5.65±0.16	69.39±0.61	16.62±0.62
PFSP	24.2±0.3	21.87±0.35	4.82±0.14	49.55±0.3	15.01±1.84

WSI-water solubility index; WAI-water absorption index; FAI-fat absorption index; SP- swelling power.

of fresh samples were 1.08 and 0.9 mL NaOH. 100 g^{-1} (dry sample) (OFSP and PFSP, respectively) and of flours were 0.91 and 0.87 mL NaOH.100 g^{-1} (DW) (OFSP and PFSP, respectively). A small descrease of acidity was observed after processing. These values are in accordance with Roesler *et al.* (2008), who reported an acidity content ranging of 0.65 to 2.48 mL NaOH. 100 g^{-1} (DW) for different cultivars of sweet potatoes. Leonel *et al.* (1998) found a mean value of 0.93 mL NaOH. 100 g^{-1} (DW) for sweet potato starch, which is similar to acidity contents of organic sweet potatoes flours reported in this study.

Determination of technological quality of organic OFSP and PFSP flours

Yields, water solubility index (WSI), water absorption index (WAI), fat absorption index (FAI) and swelling power (SP) of organic OFSP and PFSP flours are presented in Table 3. Yields of different flours presented no difference and were similar to the values obtained by Vieira and Silva (2010) (26.3 and 24%) who also evaluated flours obtained by two different cultivars of sweet potatoes. The water solubility index (WSI) is related to the amount of soluble solids on a dry sample, allowing to check the severity of the treatment, depending on the degradation, gelling, dextrinization and consequent solubilization of starch. A low WSI indicates less degradation of starch by rupture of the molecule and thus greater absorption of water, which positively reflect in the rate of water absorption (WAI) (Oak *et al.*, 2002). These same authors, when evaluating the effect of extrusion parameters in mixtures of wheat flour, rice and banana, concluded that under conditions of high temperature WSI was higher, indicating greater degradation of starch granules.

The WSI were higher for OFSP flour (38.87 to 38.90%) compared to PFSP flours. Yadav *et al.* (2006) found solubility index of 20 to 30% for sweet potato flour obtained by different methods. Jangchud *et al.* (2003) found WSI of 21.4 to 51.3% for orange and purple sweet potato flours, unbleached and bleached at different temperatures. Shih *et al.* (2009) obtained WSI of 18.2 to 52% for extruded orange and yellow sweet potatoes. Ahmed *et al.* (2010b) obtained WSI of 22.40 to 27.23% for sweet potato flours obtained by drying at different temperatures. Abegunde *et al.* (2013) found WSI from 8.56 to 19.97% in starches extracted from different varieties of sweet potato. Ahmed *et al.* (2010) evaluated PFSP flours obtained by spray drying, for different concentrations of encapsulating material, obtaining WSI between 44.97 and 82.19%, higher than found in this study, which can be explained by the difference in the method of production, and even the presence of the wall materials.

According to Faubion and Hoseney (1982), WAI is an indicative of the availability of molecules of hydrophilic groups (such as hydroxyl) to interact with water molecules. The water absorption rates are related to the degree of degradation of macromolecules, which interferes with the ability thereof to absorb water (Guha *et al.*, 1997). OFSP presented highest WAI. Similar values were obtained by Singh *et al.* (2003), who evaluated potatoes flour obtained by drying (5.6 to 5.82%). Ahmed *et al.* (2010) found WAI of 0.86 to 1.48% for encapsulated flours, and 1.14% for non-encapsulated PFSP flours, obtained by spray drying. Ahmed *et al.* (2010a) reported WAI of 2.27% in sweet potato flours dried at 65 °C.

High FAI is desirable in products such as meat extenders, viscous products such as soups, processed cheese and pasta, it improves mouthfeel (Cheftel *et al.*, 1989). These authors further argue that the mechanism of AG is mainly attributed to physical retention of lipids by protein modification and it can increase or decrease the AG. Wall (1979) found that a protein can serve as humectant and emulsifier and fat. Orange and purple fleshed sweet potatoes presented FAI of 69.4% and 49.55%, respectively. These results differed from those found by Osundahunsi *et al.* (2003) for red (9 to 12%) and white sweet potato flours (10%), which have lower absorption capacity for flour fat studied. According to Ayadi *et al.* (2009), fibers may be responsible for increase water absorption capacity and, consequently, of fat. This behavior was observed in the present study, as the BDPA flours showed higher FAI, compared to flours PFSP, which can be explained by the fact that they have higher content of crude fiber (Table 1).

Jangchud *et al.* (2003) evaluated sweet potatoes flours, obtaining SP of 7.4 to 29.2 mL. g^{-1} in OFSP flours and 7 to 24.3 mL. g^{-1} in PFSP flours. Abegunde *et al.* (2013) found swelling power ranging from 13.46 to 26.13 mL. g^{-1} for sweet potatoes starch

NUTRITIONAL FACTS OF ORGANIC ORANGE-FLESHED SWEET POTATO FLOUR Serving a quarter cup (50 grams)		
	Amount per serving	% DV*
Calories	191 Kcal= 798 KJ	9,5
Carbohydrates (g)	45,3	9,1
Protein (g)	2,13	0,43
Vitamin A (µg EAR)[1]	768	85,3
Not contain significant contents of total fats, saturated fats, trans fats, dietary fiber and sodium.		
(*) Percent Daily Values are based on a diet of 2000 kcal or 8400 kJ. Daily values can be higher or lower depending on your calorie needs.		

Figure 1. Nutritional facts of organic orange-fleshed sweet potato flour

[1] Vitamin A content (µg RAE), expressed as retinol activity equivalent (RAE) according to IOM (2001) and RDI (recommended daily intake) of vitamin A for adults (900 µg RAE/ day) .

NUTRITIONAL FACTS OF ORGANIC PURPLE-FLESHED SWEET POTATO FLOUR Serving a quarter cup (50 grams)		
	Amount per serving	% DV*
Calories	190 kcal= 794 KJ	9,5
Carbohydrates (g)	44,13	8,8
Proteins (g)	2,91	0,14
Not contain significant contents of total fats, saturated fats, trans fats, dietary fiber and sodium.		
(*) Percent Daily Values are based on a diet of 2000 kcal or 8400 kJ. Daily values can be higher or lower depending on your calorie needs.		

Figure 2. Nutritional facts of purple-fleshed sweet potatoes flour

[1] Vitamin A content (µg RAE), expressed as retinol activity equivalent (RAE) according to IOM (2001) and RDI (recommended daily intake) of vitamin A for adults (900 µg RAE/day) .

obtained from 11 different cultivars. Ahmed *et al.* (2010) found SP from 1.92 to 2.56 mL. g^{-1}. A study taken by Adeleke and Odedeji (2010) evaluated the influence of wheat flour addiction on the quality of sweet potatoes flours, and obtained SP of 8.63 mL. g^{-1} for wheat flour, 6.01 mL / g for sweet potato flour and 6.35 to 6.85 mL. g^{-1} for mixed flours. Aina *et al.* (2009) reported SP values ranging from 6.7 to 23.5 mL. g^{-1}, for sweet potatoes flours obtained from different varieties.

Nutritional facts of organic flours

In Figure 1, it is shown the nutritional facts of organic orange-fleshed sweet potatoes flours, including its vitamin A content, and in Figure 2, it is shown the nutritional facts of organic purple-fleshed sweet potatoes flours.

The portion size for cereals and tubers flours is 50 g, corresponding to a quarter cup (BRASIL, 2003b). In nutritional facts charts, carbohydrates, proteins and fibers were considered in order to calculate the total calories. Total, saturated and trans fats, sodium and fiber contents of organic flours present no significant amounts, thus they are labeled as "not significant".

The calories of a portion of OFSP and PFSP flours were 191 and 190 kcal, corresponding to 9.5% of the daily value (DV) for a 2000 calorie diet values. An interesting finding is that the consumption of 50 g of OFSP flour accounted for 85.3% of the recommended daily value for vitamin A.

Conclusion

The results show that the chemical composition of fresh organic sweet potatoes its flours is in agreement to literature, and have an excellent nutritional profile. From a nutritional standpoint, the organic flours presented an interesting physico-chemical composition, with high protein, carbohydrates, starch and fiber contents, and the consumption of organic orange-fleshed sweet potato flour can increase the intake of nutrients such as vitamin A. Furthermore, these flours can be used to fortify food products, providing higher levels of phytochemicals as carotenoids and anthocyanins.

Yields of the evaluated flours show that they are viable for preparation of food products, mainly for baking. The organic flours showed interesting index of water, index of water absorption, index of fat absorption and swelling power, which suggests a great technological quality and viability of their incorporation in several kinds of food products.

Acknowledgements

Financial support from CNPq (National Council for Scientific and Technological Development), FAPERJ (State of Rio de Janeiro Research Foundation), PROEXT/MEC/Sesu 2011/2012 and CAPES-2011/2012 (Pró-equipamento Program) are gratefully acknowledged.

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