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Promotion of orange flesh sweet potato by demonstration of acceptance and food product development

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Orange flesh sweet potato (OFSP) is a globally important staple crop. Health benefits of OFSP are substantial, especially for nutrition-endangered populations. Compared to the Irish potato (IP), OFSP is a richer source of nutrients and fiber. In some parts of the world, OFSP is unfortunately regarded as a poor farmer's crop. This negative reputation has resulted in reduced acceptance of OFSP by populations that could benefit greatly from it. One purpose of this paper is to promote acceptance of OFSP by demonstrating sensory preference of OFSP compared to IP. The second purpose is to recognize a global effort to develop food products using OFSP. Consumer taste tests were conducted to compare OFSP and IP cooked and prepared using common methods of mashing and cubing. Published journal articles that reported development of foods with OFSP as a primary ingredient were identified. Recipe developers must have used a rigorous technique of sensory analysis to test products. Consumers did not show a significant preference for the taste or appearance of mashed or cubed OFSP compared to IP. Researchers from 9 different countries have developed food products that included OFSP in 22 different categories over a 26-year period. OFSP has been successfully utilized in the development of many well-liked food products. Continuous education and exposure of future generations of scientists and consumers to the benefits of OFSP will result in broad-based acceptance.

Key words: Orange flesh sweet potato, Irish potato, sensory test, acceptance, product development.

INTRODUCTION

Sweet potato (*Ipomoea batatas*) plays a major role worldwide as a staple crop and is especially important in developing countries (Laurie et al., 2015). Sweet potato is thought to have originated in Latin America (Davidson,

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Table 1. Production elements for potato (*Solanum tuberosum*) and sweet potato (*Ipomoea batatas*), International Potato Center (2013).

Crop	Establishment method and days to harvest	Planting depth	Fertility Kg/hectare	Potential insect pests	Potential plant diseases
Potato	Tuber seed pieces 100-120 days	7.6-10.2 cm deep	112-112-336 N--P--K	Colorado potato beetle, potato tuber moth, Leafminer, Cyst-nematode	Late blight, bacterial wilt, potato blackleg
Sweet potato	Stem cuttings 60-120 days	2-3 stem nodes deep	56-78-78 N--P--K	Sweet potato weevil, Whitefly, various nematodes	Sweet potato virus disease

Table 2. Water and energy content and nutrient density found in orange flesh sweet potato (OFSP), OFSP leaves and Irish potatoes (IP) (USDA, 2016).

Nutrient	IP	OFSP	Raw OFSP leaves
Water (g)	81.6	77.3	86.8
Energy (kcal)	69	86	42
Protein (g/100 g)	1.68	1.57	2.49
Fat (g/100 g)	0.1	0.1	0.51
Carbohydrates (g/100 g)	16	20	8.8
Fiber (g/100 g)	2.4	3.0	5.3
Calcium (g/100 g)	9	30	0.08
Iron (g/100 g)	0.52	0.61	
Magnesium (g/100 g)	21	25	0.07
Phosphorus (g/100 g)	62	47	0.08
Potassium (g/100 g)	407	337	0.51
Zinc (g/100 g)	0.29	0.30	
Vitamin C (g/100 g)	9.1	2.4	0.011
Thiamin (mg/100 g)	0.07	0.08	0.16
Riboflavin (mg/100 g)	0.03	0.06	0.35
Niacin (mg/100 g)	1.07	0.56	1.13
Vitamin B6 (mg/100 g)	0.20	0.21	0.19
Folate (µg/100 g)	18	11	1
Vitamin A (RAE/100 g)	0	709	189
Vitamin E (mg/100 g)	0.01	0.26	
Vitamin K (µg/100 g)	1.6	1.8	302

1999). From the Americas, the Spanish brought the sweet potato to Europe, where it spread to Africa, India, China and Japan (Katayama et al., 2017). It is hardy, has low input requirements and is a versatile crop (Laurie et al., 2015). Table 1 describes optimum cultivation parameters for growing IP and OFSP. Significantly longer time to harvest and higher fertility requirements are needed for IP production compared to OFSP.

The orange flesh sweet potato (OFSP) has significant antioxidant activity, and can potentially improve vitamin A status in children (Laurie et al., 2015; Hotz et al., 2012; Li and Mu, 2012; Burri, 2011). Emerging health benefits of the OFSP are substantial, making it an even more important food –especially for populations in danger of malnutrition (Aywa et al. 2013; Kaspar et al., 2013). Table 2 shows a comparison of water, energy, and nutrients of OFSP, raw OFSP leaves and IP. OFSP stands out as a rich source of fiber, calcium, and vitamin A compared to IP. The raw leaves of the OFSP vine provide protein, thiamin, riboflavin, niacin and vitamin A and are an excellent source of vitamin K and fiber. Rautenbach et al. (2010) asserts that OFSP contains polyphenols at a similar level found in fruits and also has an oxygen radical absorbance capacity (ORAC) similar to many fruits.

Ojwang (2014) and others (Laurie et al., 2015; Setumo,

2014; Bienabe and Vermeulen, 2008) observed that local communities in Sub-Saharan Africa tended to favor IP and other tuber crops above OFSP for a variety of reasons. In many parts of the world, OFSP may be regarded as a mainstay for poor farmers and as a crop grown by women (Brito et al., 2012). Part of this reputation can be attributed to promotion of OFSP as a post disaster crop to increase food security (Kapinga et al., 2005). Jenkins et al. (2015) pointed out that perception of OFSP varieties may be geographically specific. Clearly, widespread promotion of OFSP is needed. The objective of this research was to help promote acceptance of OFSP by (1) demonstrating sensory preference of OFSP compared to IP by a diverse consumer group, and (2) recognizing a global effort to develop new food products from OFSP.

Consumer organoleptic tests were designed to determine consumer acceptance of flavor and appearance of IP and OFSP cooked and prepared using common methods. A neutral or preferential response to OFSP compared to IP by multi-cultural, American consumers (especially young, college-age adults) participating in this study would help reinforce the case for greater acceptance of OFSP. A review of literature was conducted to identify food product development efforts using OFSP as a primary ingredient. Use of structured sensory testing was required to consider studies as relevant. A growing, global effort to develop new food products from OFSP would also show evidence of acceptance.

MATERIALS AND METHODS

Potato cultivars

White Irish Potatoes Russet type, and Orange Flesh Sweet Potato were purchased from a Wal-Mart Supercenter (Perkins Rd, Stillwater, OK).

Preparation

The same preparation procedure was followed for each type of potato (separately and simultaneously). Potatoes were prepared immediately before being served for sensory evaluation. Individual potatoes (about 200 g each) were rinsed in tap water. Next, potatoes were peeled by hand with a swivel peeler (OXO International Ltd., New York, NY). A sharp knife was used to hand-cut potatoes into approximately 2.5 cm cubes. A brine solution was prepared by adding 4.6 g of table salt (Morton Salt, Chicago, IL) to 4 L of tap water. The brine was boiled in a steam kettle. One kg of potato cubes was dumped into the boiling water and cooked for about 13 min, until fork-tender.

Boiled potatoes were removed from the pot using a straining ladle and placed in 4-liter plastic zipper-lock bags. The bags of cooked potato cubes were stored in two insulated chests (STX-54, Igloo Products, Katy, TX) before serving. Potatoes served as cubes were removed directly from the zipper-lock bags and placed on serving plates. For mashed potatoes, the entire bag of cubes was hand kneaded in the bag. Mashed potatoes were transferred from the bag to the serving plates using an ice-cream scoop. Cooked potatoes were held for no longer than 2-hours before serving.

Sensory evaluation

Consumer tests were carried out at the Sensory Analysis Laboratory of the R.M. Kerr Food and Agricultural Products Center at Oklahoma State University. The tests were performed in several sessions during the day, with a variable number of panelists in each session. The total number of consumers that participated in the tests was 104, which was a typical number reported for consumer hedonic tests evaluating vegetables (Zhao et al., 2007; Kaspar et al., 2013). The consumer group was screened for food allergies, history of potato consumption and willingness to participate in the sensory test. Consumers were 65% female and claimed their home continent as: 83% from America; 2% from Africa; 6% from Asia; 1% from Europe and 8% from other. The consumers were mostly young college-age students with 83% of the group between 18 and 24 years of age. The remaining ages ranged from 6% between 25 to 29 years; 3% between 30 and 34 years; and, 9% were 35 years or older.

Sample plates were marked for the study in advance. Paper plates were divided into four quadrants using an indelible ink marker and each plate was assigned a random, three-digit number. About 75 g of one of the following four samples were placed in the center a quadrant of every plate for evaluation: mashed and diced IP, and mashed and diced OFSP. The location of samples on the plates was randomized to balance the presentation. Hot samples were placed on the plates and served immediately to panelists.

The sensory evaluation was divided into two phases that occurred in series. The purpose of the first phase was to evaluate taste and the second to evaluate appearance. The first phase was completed with the room lights turned off and red lights used to illuminate the samples. The red light masked the different colors of the potatoes. The second phase was completed under normal, florescent lighting.

Panelists were asked to evaluate samples in both phases using a hedonic scale from 1 to 9, with 1 = dislike extremely, and 9 = like extremely. Unsalted crackers and bottled water were provided for cleansing the palate between samples. An expectorant-cup was provided if the panelist did not want to swallow the sample.

OFSP product development study selection

Published journal articles were selected that described food product development with OFSP as a primary ingredient. A systematic method of product sensory evaluation must have been incorporated in the methods. Geographical or temporal limitations were not included.

RESULTS AND DISCUSSION

Duncan's new multiple range test (MRT) was conducted for each potato treatment (Table 3). MRT is used to determine if a significant difference existed between the means. A 95% confidence level ($P < 0.05$) was selected and the analysis was conducted using SAS software (Version 8, Cary, NC). Results indicated that college-age adults evaluated the taste and appearance of mashed and cubed IP and OFSP at about the same level of preference.

Table 3. Potato Evaluations, taste testing and appearance of orange flesh sweet potatoes (OFSP) and Irish potatoes (IP).

Sample	Taste		Appearance	
Mashed OFSP	6.3	a[z]	7.5	a
Cubed OFSP	6.0	a	6.0	a
Mashed IP	6.5	a	8.2	a
Cubed IP	6.1	a	6.5	a

[z]Numbers in a column followed by the same letter exhibited no significant differences based on Duncan's Multiple Range Test where P=0.05.

Table 4. Products with OFSP ingredients that were developed by researchers and proven to be highly acceptable based on organized sensory testing.

Product	Location(s)	Reference(s)
Amala (cooked paste)	Nigeria	Fetuga et al. (2014)
Alcoholic beverage	Brazil, Assam, India	Ramos et al. (2017) and Paul et al. (2014)
Baked snack	Nigeria	Olapade and Ogunade (2014)
Bread	Nigeria, Ethiopia, Mexico	Etudaiye et al. (2015), Afework et al. (2016) and Trejo-Gonzales et al. (2014)
Cake	Nigeria	Etudaiye et al. (2015)
Chinchin (fried snack)	Nigeria	Etudaiye et al. (2015)
Chips	South Africa	Laurie and Van Heerden (2012)
Cookies: gluten free[1], peanut-sweet potato[2], sweet potato-maize blend[3])	Mississippi, USA, Georgia, USA, Nigeria	Stokes et al. (2014), Palomar et al. (1994), and Adeyeye and Akingbala (2015)
Curd (fortified with sweet potato)	Orissa, India	Sivakumar et al. (2008)
Dackere	Cameroon	Mahamat et al. (2016)
Doughnuts	South Africa	Laurie and Van Heerden (2012)
Flour	Alabama, USA	Dawkins and Lu (1991)
Gari (meal)	Kwara, Nigeria	Ojo and Akande (2013)
Jam	South Africa	Ngubane (2008)
Juice	South Africa	Laurie and Van Heerden (2012)
Leaves (cooked vegetable dish)	South Africa	Laurie and Van Heerden (2012)
Pasta	Punjab, India; Kerala, India	Singh et al. (2004) and Menon et al. (2016)
Pastry	Cebu, Philippines; Laguna, Philippines	Aller et al. (2015) and Collado et al. (2001)
Pickle	Orissa, India	Panda et al. (2007)
Porridge (sweet potato-soybean-moringa)	Ethiopia	Gebretsadikan et al. (2015)
Tortillas (sweet potato puree and soy)	Louisiana, USA	Gelin et al. (2003)
Yoghurt	Louisiana, USA	Al-Fayez (2000)

For the taste tests, red lights prevented the panelists from distinguishing between OFSP and IP based on color. The red lights were turned off during the evaluation of the samples' appearance. Standard, fluorescent lights illuminated the room for the visual tests. Results of this study were consistent with Kaspar et al. (2013), where consumers did not detect significant differences between potato cultivars, and Tomlins et al. (2007) where consumers in the lake zone of Tanzania rated OFSP as highly acceptable.

Students at Oklahoma State University tend to represent diverse food consumer groups because of their eclectic eating habits and the prolific range of international cuisines available. Even so, in 2015, American consumers utilized 51.5 kg of IP per capita (National Potato Council, 2016) compared to 3.3 kg of OFSP (Bond, 2017). Given the ratio of IP to OFSP consumption was greater than 15:1, it is remarkable that no significant difference was found in the sensory tests. Further studies are needed to explore the taste and

appearance evaluations conducted by other groups representing unique segments of the consumer population for IP and OFSP. The value of repeating similar tests in global communities is indicated.

Studies by researchers on sensory evaluation and sweet potato palatability have shown that products containing OFSP are well liked. Laurie and Van Heerden (2012) reported high acceptability for doughnuts, chips and juice made from OFSP and cooked leaves from OFSP vines. A jam made from OFSP was also a local favorite (Ngubane, 2008) in South Africa. The flour and other ingredients of OFSP have been studied for use in foods (Walter et al., 1999; Dansby and Bovell-Benjamin 2003; Etudaiye et al., 2015). Table 4 lists some of the OFSP-based products developed, or under development, that have been evaluated by researchers making use of organized taste panels to evaluate their results.

Based on the information presented in Table 4, separate groups of researchers operating from nine different countries investigated food products containing OFSP or its leaves. Research spanned a 26-year period, with 27%, of the articles listed published in the past five years. This is important news for researchers, growers and consumers of OFSP, because the trend to develop nutritious and good-tasting products containing OFSP appears to be geographically widespread, long-term and persistent.

A continuous stream of healthy, affordable, and attractive products containing OFSP-based ingredients are presently available. New products containing ingredients from OFSP are expected to be developed, tested and commercialized in the future. Products containing ingredients from OFSP, or its leaves, will increasingly contribute to improving the health and wellbeing of many consumers worldwide.

Limitations and challenges to the continued promotion and acceptance of OFSP primarily reside within the sphere of education. Superior health benefits, sensory acceptance and vigorous product development activity combine to give compelling evidence of the value of OFSP-based foods. The story of the full value of OFSP to the food chain must be developed and expounded to future generations of scientists and consumers. Promotion will no longer be required when the truth about OFSP is comprehended on a wide-scale.

Successful marketing of OFSP products may be challenged by many factors such as trade laws, product shelf-life, customs, climactic conditions, politics, income and packaging. Ideally, acceptance should not become a marketing issue for a proven food source that is as fundamentally important to human health and wellbeing as OFSP. Education on the merits of OFSP will result in acceptance; acceptance in turn will result in demand. Demand can be expected to drive marketing of OFSP-based products to new and sustainable levels.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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