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Physicochemical Properties of Wheat - Carrot Composite Flours for Pasta Processing

Sule Stephen*, Abu Joseph Oneh and Igyor Michael Agba

Abstract

In a previous survey, carrot was identified as a potential pro-vitamin A fortificant for pasta products. In this study, carrot powder was incorporated into wheat flour at 5, 10, 15, 20, 25 and 30%.The resulting composite flours were analyzed for physicochemical properties. Incorporation of carrot powder at up to 30% in wheat flour led to significant ($p<0.05$) improvement in beta carotene content from 1.15 to 6.83 mg/100g, as well as vitamins B_1 (0.49 to 0.52 mg/100g), B_3 (3.74 to 4.23 mg/100g), B_6 (0.41 to 0.60 mg/100g), C (0.62 to 3.69 mg/100g), E (0.73 to 1.85 mg/100g) and K (1.88 to 31.86 µg/100g). Bulk density (0.64 to 0.76 gml^{-1}), water absorption capacity (2.00 to 3.20 g/g), oil absorption capacity (2.78 to 3.41 g/g) and swelling index (1.09 to 1.58) increased significantly ($p<0.05$) with up to30% carrot powder incorporation into wheat flour, while foaming capacity reduced from 12.71 to 10.73%. Furthermore, peak (215.70 to 312.30 RVU) and final (229.40 to 330.00 RVU) viscosities of the composite flour blends significantly ($p<0.05$) increased with increasing carrot powder up to 30%. The control flour (100% wheat flour) displayed the lowest pasting temperature (69.50°C). These changes in the physicochemical properties of wheat-carrot composite flours could be exploited in the processing of pasta and related products.

Sule Stephen, Abu Joseph Oneh and Igyor Michael Agba
Department of Food Science and Technology,
University of Agriculture, Makurdi.

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Introduction

The use of composite flours in food product development has become an increasing practice for food processors in order to provide certain nutritional advantages and to overcome individual flour limitations. Composite flours are either binary or ternary mixtures of flours from two or more plant sources (Shittu *et al.,* 2007).

Composite flours are useful as they tend to encourage the use of locally grown crops as flour, while reducing the cost of wheat flour importation in developing countries (Hasmadi *et al.*, 2014).

Furthermore, since wheat is low in micronutrients, extensive consumption of wheat-based based foods such as pasta might predispose individuals to micronutrient malnutrition and its associated burdens. Supplementation of wheat flour with readily available and inexpensive staples could improve the nutritional quality of wheat-based products such as pasta (Sharma *et al.*, 1999).

A recent study identified the significant contribution of pasta products to the diets of under-five children in Makurdi, Nigeria (Sule and Abu, 2017).In the same study, carrot was identified by caregivers of under-five children as one of the most preferred pro-vitamin A fortificant for pasta processing. Carrot is a popular root vegetable grown in most parts of the world and is one of the most important sources of dietary carotenoids (pro-vitamin A) in many countries (Torronen *et al.,* 1996).Carrots are also good sources of ascorbic acid, sugars and fibre (Haq and Prasad, 2015).

However, nutrient enrichment considerations ought not to be the only factor to consider in the development of composite flours for targeted end food products such as pasta. The prediction of the potential performance of the composite flours through physicochemical analyses prior to actual food processing is also critical. Information regarding the effect of carrot powder incorporationintowheat flour on the physicochemical properties of the composite flours is lacking. This study provides some baseline information on the physicochemical properties of wheat-carrot composite flour blends for use in pasta and related products.

Materials and Methods

Procurement of Materials

Wheat (*Triticum durum*) flour and carrot (*Daucus carota*) roots used in this study were purchased from Modern Market, Makurdi, Benue State. They were transferred to the Drying Processing Laboratory of the Department of Food Science and Technology, University of Agriculture, Makurdi for subsequent processing.

Preparation of Carrot Powder

Carrot powder was prepared according to the method described by Krishan *et al.* (2012) with slight modifications. Sound fresh carrot roots were washed, then scraped using knives to remove the outer skin. The scraped roots were grated using a grater (3/16" pore size) and soaked in water (25 ± 2°C) containing 0.2% potassium metabisulphite for 3 min followed by draining using a colander and spread on trays to dry in a hot air oven (GENLAB, England B6S, serial no: 85K054) at 50°C for 10 h. The dried grated carrots were milled using a hammer mill (Brook Crompton, Huddersfield England, BS 5000-99) and sieved (425 microns) to obtain fine powder. The powder was then packaged in high density poly ethylene bags and kept at 25 ± 2°C until further use.

Blend Formulation

Composite flours were obtained by blending wheat flour and carrot powder as follows: 100:0,95:5, 90:10, 85:15, 80:20, 75:25 and 70:30 wheat: carrot.

Methods of Analyses

Determination of proximate composition

Moisture content, crude protein, crude fat, crude fibre and ash contents of wheat flour, carrot powder and their composites were determined using standard methods of AOAC (2012). Carbohydrate content was calculated by difference as follows: % Carbohydrate = 100 – (% Moisture + % Protein + % Fat + % Ash + % Fibre).

Determination of vitamins and beta-carotene

Vitamins B_1, $B_{3,}$ $B_{6,}$ E and Kwere determined using HPLC (Model: BLC-10/11, BUCK SCIENTIFIC, USA) techniques as described by AOAC (2012). Vitamin C was determined according to the method described by Mohammed *et al*. (2009) using HPLC (Model: BLC-10/11, BUCK SCIENTIFIC, USA). Beta carotene was determined using an atomic absorption spectrophotometer (Model: 6405 UV/VIS, Jenway, UK) according to the method of AOAC (2012).

Determination of functional properties

Bulk density, water absorption capacity, oil absorption capacity and swelling index were determined according to the method described by Onwuka (2005). Foaming capacity (FC) was determined according to the method of Narayana and Narsinga (1982).

Determination of pasting properties

Pasting properties were determined using a Rapid Visco Analyzer (Model RVA 3D+, Newport Scientific, Australia) as described by Newport Scientific (1998).

Statistical Analysis

Experiments were conducted in duplicates. Data obtained were statistically analyzed using analysis of variance (ANOVA). Means were separated by Fischer's Least Significance Difference Test and significant difference was accepted at 5% level of probability ($p < 0.05$) using the GenStat statistical package (17^{th} edition).

Results and Discusion

Proximate Composition of Wheat Flour and Carrot Powder

The proximate composition of wheat flour and carrot powder is presented in Table 1. The wheat flour employed in this study contained 8.9, 12.9 and 75.7% moisture, crude protein and carbohydrate respectively. On the other hand, the carrot powder contained 1.6, 7.1 and 6.8% crude fat, crude fibre and ash respectively. These results are similar to previous reports (Shyamala and Jamuna, 2010;Gazalli*et al.*, 2013).

Carrot powder is also known to contain high fibre content (Shyamala and Jamuna, 2010; Kassegn, 2016). Consequently, the higher ash content (6.80%)of carrot powder compared to wheat flour (0.45%) might be indicative of a higher concentration of minerals in the former than in the latter. On the other hand, the higher carbohydrate (75.53%) content of wheat flour suggests that the addition of carrot powder to wheat flour could lower the energy value of the resulting pasta.

Beta-carotene and Vitamin Contents of Wheat-Carrot Composite Flours

The beta-carotene content of wheat flour increased (1.15 to 6.83 mg/100g) significantly ($p<0.05$) with the incorporation of carrot powder in a concentration dependent manner (Table 2). The recommended dietary allowance of 4.8 mg/100g for children below 8 years (Institute of Medicine, 2000) was satisfied at 25% carrot powder incorporation, implying that pasta with an onward of 25% carrot powder may deliver adequate beta-carotene (pro-vitamin A) activity. An important function of beta carotene is its role in vision (Handelman, 1996). Furthermore, improvements in vitamins B_1 (0.49 to 0.52 mg/100g), B_3 (3.74 to 4.23 mg/100g), B_6 (0.41 to 0.60 mg/100g), C (0.62 to 3.69 mg/100g), E (0.73 to 1.85 mg/100g) and K (1.88 to 31.86 μg/100g) contents were proportional to the concentration of carrot powder in the composite flours. This trend would be expected in the resulting pasta from these composite flours.

The importance of vitamins in the diet are well documented in literature (FAO/WHO, 2002).Similar improvements in vitamin contents have been reported for millet-carrot composite flours (Omachi and Yusufu, 2017).

Functional Properties of Wheat-Carrot Composite Flours

Bulk density (0.64 to 0.76 gml^{-1}), water absorption capacity (2.00 to 3.20 g/g), oil absorption capacity (2.78 to 3.41 g/g) and swelling index (1.09 to 1.58) increased significantly ($p<0.05$) with carrot powder incorporation up to 30%, whereas, foaming capacity decreased from 12.71 to 10.73% (Table 3).

The increase in bulk density could be attributed to the increase in fibre to increase water absorption capacity of foods (Chen *et al.*, 2011). This could be a demerit in pasta for children below five years, given their relatively small stomach coupled with their high energy requirements.

However, the increment in water and oil absorption capacities of the composite flours could lead to improvement in the flavor and texture of pasta, thus improving sensory acceptability (Kain and Chen, 2008).

Pasting Properties of Wheat-Carrot Composite Flours

Pasting properties of wheat and carrot composite flour blends is presented in Table 4. The significant ($p<0.05$) increase in peak viscosity (215.700 to 312.30 RVU) is an indication of the swelling capacity and bulkiness of the composite starch granules (Chinma *et al.,* 2009). Consequently, if these wheat-carrot composite flours are employed during pasta processing, elevated starch thickening is to be expected. The correlation observed in this study between final viscosity and peak viscosity is consistent with the work of Tsakama *et al.* (2010), who also linked increase in final viscosity with re-association of amylose molecules. Bamigbola *et al.* (2016) reported similar final viscosity values for composite flours from wheat, carrot, tigernut and plantain.

On the other hand, the decrease in breakdown viscosity (30.25 to 15.00 RVU) seems to suggest an increasing heat and shear stability of the composite flours during cooking (Zaidhul*et al.*, 2007).Consequently, pasta from 100% wheat flour could collapse more readily during heating at high temperatures. The observed decrease in setback viscosity (49.80 to 30.94 RVU) is an indication of higher resistance to retrogradation (Sanni *et al.,* 2004) when employing the wheat-carrot composite flours. Higher amylose starches have been found to produce higher setback viscosities, which is an indication of possible reduced digestibility of the developed product (Shittu *et al.,* 2007).However, the increase in pasting temperature (69.50°C wheat flour to 80.00°C wheat-carrot composite flour)might have implications on the stability of heat labile components in the pasta and could imply higher energy requirements for cooking (Arinola *et al.*, 2016).

Table 1: Proximate Composition (%) of Wheat Flour and Carrot Powder

Raw Material	Moisture	Protein	Fat	Fibre	Ash	Available carbohydrate
Wheat Flour	8.90 ± 0.08	12.86 ± 0.12	1.40 ± 0.01	0.86 ± 0.04	0.45 ± 0.01	75.53 ± 0.25
Carrot Powder	8.30 ± 0.10	6.24 ± 0.04	1.62 ± 0.03	7.14 ± 0.12	6.80 ± 0.10	69.70 ± 0.14

*Values are means ± standard deviations of duplicate determinations.

Table 2: Vitamin and Beta-carotene Content of Wheat and Carrot Composite Flours

WF: CP	B_1 (mg/100g)	B_3 (mg/100g)	B_6(mg/100g)	C (mg/100g)	E (mg/100g)	K (μg/100g)	.... (mg/100g)
100:0	0.49^{a} ± 0.01	3.74^{a} ± 0.03	0.41^{a} ± 0.01	ND	0.73^{a} ± 0.02	1.88^{a} ± 0.05	ND
95:5	0.50^{ab} ± 0.01	3.84^{b} ± 0.04	0.44^{a} ± 0.02	0.62^{a} ± 0.02	0.91^{b} ± 0.02	6.87^{b} ± 0.40	1.15^{a} ± 0.03
90:10	0.51^{b} ± 0.01	3.91^{c} ± 0.01	0.48^{b} ± 0.01	1.23^{b} ± 0.03	1.09^{c} ± 0.01	12.03^{c} ± 0.66	2.26^{b} ± 0.05
85:15	0.51^{b} ± 0.01	4.00^{d} ± 0.02	0.51^{b} ± 0.01	1.87^{c} ± 0.02	1.27^{d} ± 0.02	17.04^{d} ± 1.06	3.43^{c} ± 0.04
80:20	0.51^{b} ± 0.00	4.07^{e} ± 0.03	0.55^{c} ± 0.02	2.47^{d} ± 0.03	1.46^{e} ± 0.03	21.06^{e} ± 2.14	4.53^{d} ± 0.04
75:25	0.51^{bc} ± 0.00	4.17^{f} ± 0.02	0.57^{cd} ± 0.02	3.10^{e} ± 0.02	1.64^{f} ± 0.03	26.43^{f} ± 2.17	5.67^{e} ± 0.03
70:30	0.52^{c} ± 0.01	4.23^{g} ± 0.03	0.60^{d} ± 0.02	3.69^{f} ± 0.04	1.85^{g} ± 0.01	31.86^{g} ± 2.20	6.83^{f} ± 0.03
LSD	0.01	0.05	0.03	0.04	0.04	2.63	0.06

*Values are means ± standard deviations of duplicate determinations. Means with same superscript in same column are not significantly ($p>0.05$) different. Key: WF- wheat flour, CP- carrot powder, ND- not detected, LSD- least significant difference.

Table 3: Functional Properties of Wheat and Carrot Composite Flours

WF: CP	BD (gml^{-1})	WAC (g/g)	OAC (g/g)	SI	FC (%)
100:0	$0.64^{a} \pm 0.01$	$2.00^{a} \pm 0.02$	$2.78^{a} \pm 0.01$	$1.09^{a} \pm 0.02$	$12.71^{a} \pm 0.08$
95:5	$0.66^{a} \pm 0.02$	$2.30^{b} \pm 0.03$	$2.87^{b} \pm 0.03$	$1.30^{b} \pm 0.03$	$12.37^{b} \pm 0.02$
90:10	$0.67^{ab} \pm 0.01$	$2.63^{c} \pm 0.06$	$2.95^{c} \pm 0.05$	$1.34^{bc} \pm 0.03$	$12.07^{c} \pm 0.03$
85:15	$0.68^{bc} \pm 0.04$	$2.80^{d} \pm 0.02$	$3.02^{d} \pm 0.02$	$1.38^{cd} \pm 0.02$	$11.54^{d} \pm 0.03$
80:20	$0.71^{c} \pm 0.01$	$3.00^{e} \pm 0.03$	$3.05^{d} \pm 0.01$	$1.43^{d} \pm 0.03$	$11.36^{e} \pm 0.04$
75:25	$0.71^{c} \pm 0.01$	$3.10^{f} \pm 0.05$	$3.14^{e} \pm 0.07$	$1.58^{e} \pm 0.03$	$11.06^{f} \pm 0.02$
70:30	$0.76^{d} \pm 0.02$	$3.20^{g} \pm 0.02$	$3.41^{f} \pm 0.05$	$1.58^{e} \pm 0.07$	$10.73^{g} \pm 0.03$
LSD	0.03	0.06	0.06	0.06	0.07

*Values are means ± standard deviations of duplicate determinations. Means with same superscript in same column are not significantly ($p > 0.05$) different.

Key: WF- wheat flour, CP- carrot powder, BD- bulk density, WAC- water absorption capacity, OAC- oil absorption capacity, SI- swelling index, FC-foaming capacity, LSD- least significant difference.

Table 4: Pasting Properties of Wheat and Carrot Composite Flours

WF: CP	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Breakdown Viscosity (RVU)	Final Viscosity (RVU)	Set Back Viscosity (RVU)	Peak Time (min)	Pasting Temp (^{o}C)
100:0	215.70^{a} ± 0.01	141.00^{a} ± 1.13	30.25^{a} ± 0.35	229.4^{a} ± 0.00	49.80^{a} ± 0.01	6.07^{a} ± 0.01	69.50^{a} ± 0.00
95:5	237.60^{b} ± 0.64	133.70^{b} ± 0.00	29.10^{b} ± 0.85	254.9^{b} ± 0.01	47.81^{b} ± 0.00	5.13^{b} ± 0.01	72.60^{b} ± 0.00
90:10	250.80^{c} ± 0.35	130.30^{c} ± 0.01	26.91^{c} ± 0.01	266.8^{c} ± 1.06	45.20^{c} ± 0.01	5.06^{c} ± 0.02	73.09^{c} ± 0.15
85:15	263.80^{d} ± 0.01	123.00^{d} ± 0.06	24.09^{d} ± 0.01	277.7^{d} ± 0.62	42.05^{d} ± 0.08	4.93^{d} ± 0.02	75.59^{d} ± 0.01
80:20	278.30^{e} ± 0.00	118.20^{e} ± 0.01	21.40^{e} ± 0.71	292.4^{e} ± 0.71	38.23^{e} ± 0.00	4.73^{e} ± 0.01	76.30^{e} ± 0.01
75:25	299.90^{f} ± 0.01	114.00^{f} ± 1.34	18.34^{f} ± 0.01	315.8^{f} ± 0.00	35.96^{f} ± 0.00	4.67^{f} ± 0.01	78.20^{f} ± 0.01
70:30	312.30^{g} ± 0.01	98.20^{g} ± 0.00	15.00^{g} ± 0.01	330.0^{g} ± 0.00	30.94^{g} ± 0.07	4.52^{g} ± 0.01	80.00^{g} ± 0.00
LSD	0.65	1.57	1.04	1.27	0.09	0.03	0.13

*Values are means ± standard deviations of duplicate determinations. Means with same superscript in same column are not significantly ($p>0.05$) different. **Key:** WF- wheat flour, CP- carrot powder, LSD- least significant difference.

Conclusion

Incorporation of carrot powder into wheat flour improved beta carotene and vitamin contents of the composite flours. Furthermore, the increasing water absorption capacity, peak and final viscosities could be exploited in pasta processing and also in the development of other related food products.

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