EFFECT OF DEBITTERING METHODS ON THE CHEMICAL AND
PHYSIOCHEMICAL OF DEFATTED AND UNDEFATTED
SWEET ORANGE SEED FLOURS

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Research Article

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Abstract

The study was carried out to determine the effect of debittering methods on the chemical, physiochemical and shelf-life of flours produced from dibittered orange seeds. The orange seeds were removed manually from sweet orange fruits, soaked in water for 12 hours and then boiled at 100 °C for 30, 60, 90, 120 and 150 min, respectively. The boiled seeds were dehulled manually, ground, and a portion defatted with absolute ethanol, milled and sieved. The various defatted and undefatted orange seed flours were analyzed for chemical and physiochemical properties. The orange seed flours contained 7.53 % – 54.58 % protein, 3.94 % – 47.32 % fat, 2.53 % – 24.58 % crude fiber, 2.03 % – 6.89 % ash, 2.53 % – 61.27 % moisture content, 5.62 – 58.47 % carbohydrate, 78.10 – 295.22 oxalate, 0.0 – 196.00 Hu/mg haemaglutinin, 0.0 – 86.45 mg/100g tannins, 128.54 – 303 mg/100g pytate, 1.51 – 1.98 g/g water absorption capacity, 1.060 – 1.625 g/g oil absorption capacity, 67 – 75 % dispersibility, 14.44 – 42.00 S wetability, 59.24 – 70.42 0C gelation temperature, 5 – 20 g least gelation capacity, 0.40 – 0.69 g/cm3 and bulk density. Orange seed waste maybe transformed in to useful product due to its nutritional quality to alleviate malnutrition and produce better quality products. Substituting orange seed flour with wheat flour will improved the protein, minerals, vitamin, fat and fiber content of the composite flour.

Introduction

_Citrus sinensis_, sometimes known as orange or sweet orange (to set it from comparable species like sour orange _C. aurantium_, and mandarin orange, _C. reticulata_), is a tiny tree in the _Rutaceae_ (Citrus family). According to [1], “oranges are said to have originated in Southeast Asia and were cultivated in China by 2500 BC”, where they were known as the "Chinese" apple [2]. Citrus production in the countries and commodities covered by Citrus World Markets and Trade is expected to increase by 4% to 98 million metric tons in 2020/21 (tons). One of the best vital citrus fruit crops in the world is sweet orange, accounting for 71 % of total citrus fruit production [3]. For its excellent nutritional content, source of vitamins, and other purposes, it is now produced practically everywhere in the world as a human food source.

Fruit processing generates a lot of trash, like peels and seeds. Disposal of these items is typically a challenge, which is exacerbated by regulatory constraints. The edible portion of an orange is limited, the peels and seeds of waste materials are produced in huge quantities during the processing of orange juice and pectin manufacture, this causes the release of odors, which serves as a breeding ground for insects, as well as the creation of an unsightly environment with a reduced aesthetic outlook [4]. The edible portion of an orange is small, vast volumes of waste materials (peels and seeds) are produced during processing, thus have a negative impact on the environment [5]. When not further treated, orange by-products constitute an extremely dangerous waste that can pollute the environment [6, 7]. Citrus seeds were reported to be treasured source of plant protein and oil [8]. Previous research report showed that dehulled orange seed flour contained 54 % fat, 28.5 % carbohydrate, 5.5 % crude fiber, 3.1 % protein and 2.5 % ash[9].

There is a lot of research going on right now on how to recover, recycle, and upgrade citrus waste (peels and seeds) into higher-valued and useful goods [10]. Limonin, a tetracyclic triterpenoid, is responsible for the bitterness of orange juice. Most citrus fruits have limonic acid or limonin monolactone in their seeds and membranes, which is used to make limonin [11]. Controlling bitterness in citrus juices and citrus products is still a significant topic of study [12].

Materials And Methods

_Materials_: Sweet orange (_Citrus sinensis_) fruits were purchased from Obollo and Ibagwa market in Enugu State, Nigeria.

_Preparation of debittered defatted orange seed flour_: Sweet orange fruits were cut into halves with clean sharp knife and the seeds were removed manually and sun dried. The orange seeds were cleaned in tap water. The orange seeds (20 kg) were soaked in tap water (1:10, seed : water) for 12 h. Thereafter, the hydrated seeds were boiled for 30, 60, 90, 120 and 150 min, respectively. All the samples were dehulled manually, winnowed, oven dried at 60 °C for 12 h and grounded with corolla hand grinding machine. The oil was extracted from the orange seeds with ethanol using Soxhlet apparatus and the defatted flour was milled and sieved through 60 mesh sieve. The flow chart for the preparation of debittered orange seed flour is shown in Figure 1.

_Preparation of debittered undefatted orange seed flour_: Sweet orange fruits were cut into halves with clean sharp knife and the seeds were removed manually and sun dried. The orange seeds were cleaned in tap water. The orange seeds (20 kg) were soaked in tap water for 12 h. Thereafter, the hydrated seeds were boiled for 30, 60, 90, 120 and 150 min, respectively. All the samples were be dehulled manually, winnowed, oven dried at 60 °C for 12 h and ground with corolla hand grinding machine. The flow chart for the preparation of debittered orange seed flour is shown in Figure 2.
Analytical methods: Proximate composition was determined by the method as described by the [13]. Carbohydrate was calculated by difference as described by [14]. Tannin and phytate was determined by the Folin-Denis spectrophotometric method as described by [15]. Oxalic acid was determined by the titration method of [13] while Hemagglutinating activity was estimated by a serial dilution procedure using human type A erythrocytes suspension. The hemagglutinin patterns in the various wells were read [16]. Water absorption capacity and oil absorption determined using the procedure of [17]. Least gelation concentration was determined by the method of [18]. Foaming capacity and bulk density were determined by the method of [19]. Wettability were determined according the method described by [20]. Gelatinization temperature was as determined by [21]. Standard method was used for determining dispersibility [22].

Statistical Analysis: The experiment was carried out on split-plot in completely randomized design. Data generated were analysed using analysis of variance (ANOVA). Least significant difference (LSD) test was used to separate means that were significantly different. Significance was accepted at p < 0.05.

Results And Discussions

Effect of debittering methods on proximate composition of flour

The moisture contents of the samples ranged from 2.93 % to 18.79 % (Table I). “The highest moisture content was found in wheat flour (18.79%)”, while the lowest moisture content was found in 150 minute boiled defatted orange seed flour (2.53 %). The interactions between the moisture content of defatted and undefatted samples of the flours were significantly (P < 0.05) different. This implies that the moisture content was behaving differently with increase in boiling time. The orange seed flour’s storage stability would be improved by the low moisture content. Flour with a lower moisture content has better shelf stability and thus quality [23]. Moisture is also critical for the safe storage of cereals and their products in terms of microorganisms, especially certain fungi species.

The protein contents of the flour samples ranged from 13.27 % to 54.58 % (Table I). The defatted debittered orange seed flour (25.58 % - 54.58 %) had higher protein content than the undefatted debittered orange seed flours which ranged from 18.56 % - 36.65 %. Similar observation was also reported by [24] and [25], where defatting increased protein concentration. These values were, still, higher than 3.1 % protein reported by [8], however, the protein content of 120 and 150 min boiled undefatted orange seed flour (18.92 % and 18.51 % respectively) were similar to 17.9 % for bitter orange seed flour reported by [26] and [27]. The variation could be ascribed to varietal changes, stage of maturation of the seeds and environmental conditions [28].

Wheat flour had the lowest protein content (13.27 %) while the defatted orange seed flour boiled for 150 min had the highest protein content of 54.58 %. Increase in boiling time increased the content of protein among the defatted orange seed flours, however the protein content reduced with increase in boiling time among the undefatted sample. The interactions between defatted and undefatted orange seed flours samples were significantly (P < 0.05) different. Hence, the orange seed flours were behaving differently with increase in boiling time. This implies that, the protein content of the flours depends on boiling period. The significant interaction showed that, while the protein content of the undefatted flours samples decreased with boiling time, the protein content of defatted orange seed flour samples increased with increase in boiling time but at different rate. The defatted orange seed flours were higher in protein content than undefatted orange seed flour. The variation in the protein contents of the debittered orange seed flours could be attributed to the period of boiling. The debittering process employed in this study (boiling, with defatting) increased the protein content of the orange seed flour, similar observation was also reported by [27]. Protein is made more digestible by heating because of the inactivation of anti-nutrients [29].

The fat content of the flours ranged from 3.94 % to 47.32 % (Table I). “The fat content of the different flour samples was significantly different (p<0.05)”. The fat content was highest in the undefatted orange seed flour boiled for 30 min (47.32 %), which was significantly different from those of the undefatted seeds boiled for 30, 60, 90, 120, and 150 mins which had (41.49 %, 39.02 %, 36.26, and 31.96 %, fat contents, respectively). The wheat flour had the least fat content of 3.94 %. Boiling with defatting reduced the fat content of the orange seeds flours. The fat may have melted into the boiling water, resulting in a decrease in the fat content [30]. The bitterness of orange seed flour was reduced as the fat content of the flour was reduced. The fat content decreased with increase in the boiling time [27]. The interactions between defatted and undefatted orange seed flours samples were significantly (P < 0.05) different. Hence the orange seed flours were behaving differently with increase in boiling time. Fats are essential for the absorption of the fat soluble vitamins particularly vitamin E and vitamin A precursor, carotene with which they are usually associated.

The ash content of the flours ranged from 2.05 % to 6.80 % (Table I). “The ash content of the orange seed flour was similar to the 2.5 percent for orange seed flour reported by [8]. The ash content of the orange seed flours were significantly (p<0.05) reduced by the debittering methods. The ash content of the defatted orange seed flours (2.25 % – 5.01 %) were lower than those of the undefatted orange seed flours (3.02 % – 6.80 %). The undefatted flours boiled for 30 min had the highest ash content of 6.8 %, which was significantly
different from those of the defatted and undefatted seeds boiled for 60, 90, 120, and 150 min. "Ash content is an indication of the mineral content" [30]. The interactions between flours samples were significantly ($P < 0.05$) different. The orange seed flours behaved differently with increase in boiling time. Significant interactions also indicated that flours behaved differently from each other with defatting. The ash content of defatted and undefatted samples of the orange seed flours decreased with increase in boiling period but not at the same degree.

The crude fiber contents ranged from 3.50 % to 24.59 % (Table I), with the 150 min boiled and defatted orange seed flour having the highest value of 24.59 % which was significantly different from those of the defatted seeds boiled for 30, 60, 90, 120, and 150 mins which had (7.61 %, 7.87 %, 10.14, and 14.26 %, fiber contents, respectively), however they were higher than undefatted orange seed flours which ranged from 6.68 % to 13.03 %. Similar observation was reported by [27] that defatting increased the crude fibre content of orange seed flours. This high fiber content is important in terms of nutrition. Fibre helps to lower blood sugar levels [31]. It also promotes free bowel movement, "which aids in the easy removal of waste products from the body, as well as increased satiety, which has an impact on weight management to some extent" [32]. Dietary fiber consumption lowers the risk of coronary heart disease, stroke, hypertension, diabetes, obesity and certain gastrointestinal disorders [33, 34]. The interactions also indicated that flours behaved differently from each other with defating and boiling period. The significant interaction indicated that, fibre content of the defatted orange seed flours samples increased with boiling time, while the fibre content of undefatted orange seed flour samples also increased with increase in boiling time differently.

The carbohydrate content of the flours varied from 5.62 % - 58.47 % (Table I). Wheat flour had the highest carbohydrate content of 58.47 % while orange seed flour varied from 5.62 % to 42.13 % carbohydrate content. Flour produced from defatted orange seeds boiled for 30 min (42.13) had significantly ($p<0.05$) higher values than defatted seeds boiled for 60, 90, 120, and 150 mins which had (30.79, 27.90, 17.69 and 10.67 %, carbohydrate contents, respectively), however, they were higher than undefatted orange seed flours which ranged from 5.62 % - 27.60 %. Similar observation was reported by [27] that defatting increased carbohydrate content. The result agreed with the report of [35] that "boiling time increased the carbohydrate content of mungbean but excessive boiling reduced the carbohydrate content". The interactions between flours samples were significantly ($P < 0.05$) different. The orange seed flours behaved differently with increase in boiling time.

**Effect of debittering methods on antinutrient composition of flours**

The antinutrient composition of wheat flour and debittered orange seed flour is shown in Table II.

**Oxalate contents of orange seed flours**: The oxalate contents of the flour samples ranged from 78.10 mg/100g - 295.22 mg/100g (Table II). The oxalate concentrations were higher in the orange seed flours than in the wheat flour. The undefatted orange seed flour had higher oxalate contents (111.37 mg/100g - 295.22 mg/100g) than defatted flours (88.42 mg/100g -242.89 mg/100g). Interactions also indicated oxalate contents of defatted and undefatted orange seed flours reduced differently with boiling period. The significant interaction indicated that, oxalate content of the defatted orange seed flours samples decreased with boiling time, and oxalate content of undefatted orange seed flour samples also decreased with increase in boiling time at different rate. Oxalates and phytate are commonly reported to be responsible for most binding involving such minerals as calcium, phosphorus, iron and zinc and in preventing their absorption from digestion [36]. "High oxalates in diets can increase the risk of renal calcium absorption" [37].

**Haemaglutinin contents of orange seed flours**: The haemaglutinin contents ranged from 0 to 196.00 Hu/mg, with the 30 min boiled undefatted orange seed flour having the highest value of 196.00 Hu/mg, which was significantly different ($p<0.05$) from those of the undefatted seeds boiled for 60, 90, 120, and 150 mins which had (182.50 Hu/mg, 164.20 Hu/mg, 151.50 Hu/mg and 122.00 Hu/mg contents, respectively) (Table II). However, they all possed higher haemaglutinin content than defatted orange seed flours. Boiling and defatting reduced the haemaglutinin content of the flours. Haemaglutins was not detected in wheat flour. The interactions of haemaglutinin content between flours samples were significantly ($P < 0.05$) different. The orange seed flours behaved differently with increase in boiling time. The significant interaction indicated that, haemaglutinin content of the defatted orange seed flours samples decreased with boiling time, and haemaglutinin content of undefatted orange seed flour samples also decreased with increase in boiling time with different rate. The toxicity of hemagglutinins is destroyed by moist (but not dry) heat.

**Tannin contents of orange seed flours**: There were significant ($p<0.05$) differences in the tannin contents of the flour samples which ranged from 0 - 72.34 mg/100g (Table II). The undefatted orange seed flours had higher tannins (15.25 mg/100g - 72.32 mg/100g) than defatted orange seed flours and wheat flour. "The debettering methods reduced the tannins content of the orange seed flour". The interactions between the tannins content of defatted and undefatted orange seed flours samples were significantly ($P < 0.05$) different. This implies that the tannins content of the flours depends on boiling period and defatting. Tannins may reduce the digestibility and
palatability of proteins, lowering their quality. The tannin content of the boiled orange seeds was reduced, “which was consistent with an earlier report that processing methods such as soaking, boiling, and fermentation reduced the tannin content of foods” [38].

**Phytate contents of orange seed flours:** The phytate contents of orange seed flours ranged from 149.14 mg/100g – 303.35 mg/100g which were higher than 128.54 mg/100g of wheat flour. The phytate contents reduced in the orange seed flour with increase in the boiling time of the seeds. Undefatted orange seed flours (151.47 mg/100g – 303.35 mg/100g) had higher phytate content than defatted flours (149.14 mg/100g – 248.36 mg/100g). The interactions between defatted and undefatted orange seed flours samples were significantly (P < 0.05) different. Hence, the orange seed flours were behaving differently with increase in boiling time. By chelating with calcium or binding with substance or proteolytic enzymes, phytate can affect digestibility [37]. They are destroyed by proper heat treatment and hydrolysis.

**Physiochemical properties of flours blends**

**Water Absorption Capacity (WAC) of orange seed flours:** The water absorption capacity (WAC) of the flours ranged from 1.88 g/g to 2.88 g/g (Table III). The WAC contents increased with boiling time, probably due to structural changes in the native molecules caused by heating. The undefatted samples had significantly (p<0.05) higher water absorption capacity. This may be attributed to the higher porosity of the undefatted samples which had more space to trap water. The orange seed flours behaved differently with increase in boiling time. Interactions also showed that orange seed flours behaved differently from each other with defatting. The significant interaction indicated that, the WAC of the defatted and undefatted orange seed flours samples increased with boiling time but not at the same degree. The ability of protein to absorb water is a useful indicator of whether it can be used in aqueous food formulations [37]. Seed flours absorb more water after they’ve been heated [37].

**The oil absorption capacity (OAC) of the flours:** The oil absorption capacity (OAC) of the flours ranged from 1.38 g/g to 4.56 g/g (Table III). There were significant (p<0.05) differences in the OAC of the flours. The 150 min boiled defatted orange seed flours had the highest OAC value of 4.56 g/g which was significantly different from those of the defatted and undefatted seeds boiled for 30, 60, 90, and 120. The 100 % wheat flour had OAC value of 1.58 g/g while the 30 min boiled undefatted orange seed flours had the lowest value of 0.81 g/g. The orange seed flours behaved differently with increase in boiling time. Interactions also showed that orange seed flours behaved differently from each other with defatting. The significant interaction indicated that the OAC of the defatted and undefatted orange seed flours samples increased with boiling time but not at the same degree. All of the flour blends have a high dispersibility, which means they will easily reconstitute into fine, consistent dough or pudding when mixed [40].

**The dispersibility of orange seed flour:** The dispersibility of the flours ranged from 60 % – 84 % (Table III). The dispersibility contents decreased with the level of orange seed flour. There were significant (p<0.05) differences in the dispersibility of the flours. The orange seed flours behaved differently with increase in boiling time, interactions also showed that orange seed flours behaved differently from each other with defatting. The significant interaction indicated that the dispersibility of the defatted and undefatted orange seed flours samples increased with boiling time but not at the same degree. All of the flour blends have a high dispersibility, which means they will easily reconstitute into fine, consistent dough or pudding when mixed [40].

**The wetability of orange seed flour:** The wetability of the flours ranged from 11.34 % to 42.85 %. The wetability contents increased with boiling time. There were significant (p<0.05) differences in the wetability of the flours”. The wheat flour had the highest wetability value of 42.85 %, which was significantly different from those of the defatted and undefatted seeds boiled for 30, 60, 90, 120 and 150 mins. The orange seed flours behaved differently with increase in boiling time. Wetability is an important property in the dispersibility of food powders, which provides useful indicator of the degree to which a dried powder is likely to possess instant characteristics and needs to be studied for different powdered products[37].

**The foaming capacity of orange seed flour:** The foaming capacity of the flours ranged from 3 % to 15 % (Table III). The foaming capacity value decreased with boiling time, probably due to heat induced damage to the native molecules responsible for foaming. “There were significant (p<0.05) differences in the foaming capacity of the flours”. The 150 min boiled undefatted orange seed flours had the least foaming capacity value of 3 % (probably because of greater heat induced damage to the molecules), which was significantly different from those of the defatted and undefatted seeds boiled for 30, 60, 90, 120 and 150 mins. The 100 % wheat flour had foaming capacity value of 15 %. Defatted samples had higher foam capacity than the undefatted presumable because presence of oil in the defatted reduced the ability of the flour to foam. Oil presence is always inimical to foam formation. The orange seed flours behaved differently with increase in boiling time. Interactions also showed that orange seed flours behaved differently from each other with defatting. Forming capacity is used as indices formability of protein dispersion. “Foams are used to improve texture, consistency and appearance of foods”. Heat processing decrease foaminmg capacity [37].
Least gelation temperature of orange seed flour: The least gelation concentration (LGC) of the flours ranged from 5 g to 25 g (Table III). The LGC contents increased with boiling time. There were significant ($p<0.05$) differences in the LGC of the flours. The 120 and 150 min boiled defatted and undefatted orange seed flour had the highest LGC value of 25 g, which were significantly different from those boiled for 30, 60 and 90 except undefatted orange seed flour boiled for 60 and 90 mins. The 100 % wheat flour had LGC value of 5 g which was the lowest. Interactions showed that orange seed flours behaved differently from each other with defatting. Least gelation capacity (LGC) is a measurement of how much flour is required to form a gel in a given volume of water, which is also the lowest protein concentration at which the gel remained in the inverted tube.

The bulk density of the flours: The bulk density of the flours ranged from 0.367 g/cm$^3$ to 0.878 g/cm$^3$ (Table III). The bulk density contents reduced with boiling period, probably due to heat induced shrinkage making the flour more compact. “It’s a measure of a product’s porosity that has an impact on packaging design” with increase in boiling time, interactions also showed that orange seed flours behaved differently from each other with defatting. The bulk density of the undefatted samples probably because the process of defatting made the flour more compact. The orange seed flours behaved differently with increase in boiling time, interactions also showed that orange seed flours behaved differently from each other with defatting. The bulk density of a substance is the mass per unit volume ratio. “It’s a measure of a product’s porosity that has an impact on packaging design” [37]. The mouth feels and flavor of the food in which the flour is used are also affected by bulk density.

| TABLE I: Proximate composition of wheat flour and orange seed flours |
|----------------|----------------|----------------|----------------|----------------|----------------|
| FLOUR          | BLENDS         | PROXIMATE COMPOSITION |
|                |                | MOISTURE (%) | PROTEIN (%) | FAT (%) | ASH (%) | FIBRE (%) | CHO (%) |
| DEFATTED       | W              | 18.79±0.03   | 13.27±0.06  | 3.94±0.04 | 2.05±0.07 | 3.50±0.06 | 58.47±0.13 |
|                | DOSF30         | 2.93±0.06    | 25.58±0.07  | 15.74±0.37 | 5.01±0.01 | 7.61±0.06 | 42.13±2.99 |
|                | DOSF60         | 5.93±0.02    | 36.41±0.76  | 14.68±0.05 | 4.34±0.16 | 7.87±0.01 | 30.79±0.58 |
|                | DOSF90         | 5.91±0.04    | 39.31±0.13  | 13.53±0.11 | 3.23±0.32 | 10.14±0.04 | 27.90±0.22 |
|                | DOSF120        | 3.94±0.02    | 48.53±0.52  | 12.65±0.14 | 2.95±0.01 | 14.26±0.08 | 17.69±0.46 |
|                | DOSF150        | 2.53±0.04    | 54.58±3.88  | 7.90±0.03  | 2.25±0.04 | 24.59±0.11 | 10.67±0.23 |
| UNDEFATTED     | W              | 18.79±0.03   | 13.27±0.06  | 3.94±0.04  | 2.05±0.07 | 3.50±0.06 | 58.47±0.13 |
|                | UOSF30         | 2.94±0.04    | 36.65±0.07  | 47.32±0.45 | 6.8±0.13  | 6.68±0.22 | 27.60±0.98 |
|                | UOSF60         | 2.94±0.05    | 29.77±0.00  | 41.49±0.69 | 5.03±0.04 | 6.97±0.04 | 25.31±0.04 |
|                | UOSF90         | 3.92±0.06    | 20.93±0.37  | 39.02±0.40 | 4.06±0.08 | 7.79±0.03 | 24.28±0.78 |
|                | UOSF120        | 2.95±0.05    | 18.92±0.01  | 36.26±0.36 | 3.78±0.25 | 12.79±0.03 | 13.82±0.71 |
|                | UOSF150        | 5.92±0.04    | 18.51±0.16  | 31.96±1.20 | 3.02±0.02 | 13.03±0.02 | 5.62±0.83 |
| Fresh Seeds    | OS             | 60.27±0.07   | 7.53±0.05   | 9.62±0.05  | 2.03±0.05 | 2.55±0.11 | 7.53±0.05 |

Values are means ± standard deviation. Values in the same column carrying different superscript are significantly different ($P<0.05$)

Keys: DOSF 30 = defatted orange seed flour boiled for 30 min, DOSF 60 = defatted orange seed flour boiled for 60 min; DOSF 90 = defatted orange seed flour boiled for 90 min; DOSF 120 = defatted orange seed flour boiled for 120 min; DOSF 150 = defatted orange seed flour boiled for 150 min; UOSF 30 = undefatted orange seed flour boiled for 30 min, UOSF 60 = undefatted orange seed flour boiled for 60 min; UOSF 90 = undefatted orange seed flour boiled for 90 min; UOSF 120 = undefatted orange seed flour boiled for 120 min; UOSF 150 = Undefatted orange seed flour boiled for 150 min and W= Wheat (Control)
### Table III: Physiochemical properties of wheat flour and orange seed flours

<table>
<thead>
<tr>
<th>FLOUR</th>
<th>BLEND</th>
<th>OXALATE (mg/100g)</th>
<th>HAEMAGGLUTININ (Hu/mg)</th>
<th>TANINS (mg/100g)</th>
<th>PHYTATE (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEFATTED W</td>
<td>78.10±2.06</td>
<td>0±0</td>
<td>7.85±0.06</td>
<td>128.54±0.15</td>
<td></td>
</tr>
<tr>
<td>DOSF30</td>
<td>242.89a±1.48</td>
<td>85.00a±7.07</td>
<td>39.59a±0.07</td>
<td>246.36a±0.86</td>
<td></td>
</tr>
<tr>
<td>DOSF60</td>
<td>152.34b±0.47</td>
<td>45.00b±7.07</td>
<td>30.34b±0.44</td>
<td>226.49b±1.04</td>
<td></td>
</tr>
<tr>
<td>DOSF90</td>
<td>138.42c±0.35</td>
<td>0±0</td>
<td>24.51c±0.06</td>
<td>209.58c±0.05</td>
<td></td>
</tr>
<tr>
<td>DOSF120</td>
<td>125.32d±0.7</td>
<td>0±0</td>
<td>0±0</td>
<td>168.92d±0.98</td>
<td></td>
</tr>
<tr>
<td>DOSF150</td>
<td>88.42e±0.35</td>
<td>0±0</td>
<td>0±0</td>
<td>149.14e±0.73</td>
<td></td>
</tr>
<tr>
<td>UNDEFATTED W</td>
<td>78.10f±2.06</td>
<td>0±0</td>
<td>7.85e±0.06</td>
<td>128.54f±0.15</td>
<td></td>
</tr>
<tr>
<td>UOSF30</td>
<td>295.22a±0.83</td>
<td>196.00a±2.83</td>
<td>72.34a±0.15</td>
<td>303.35a±0.14</td>
<td></td>
</tr>
<tr>
<td>UOSF60</td>
<td>170.94b±0.86</td>
<td>182.50b±0.71</td>
<td>54.45b±0.01</td>
<td>256.82b±0.41</td>
<td></td>
</tr>
<tr>
<td>UOSF90</td>
<td>155.89c±3.46</td>
<td>164.20c±5.66</td>
<td>35.25c±1.11</td>
<td>224.76c±5.4</td>
<td></td>
</tr>
<tr>
<td>UOSF120</td>
<td>134.53d±2.68</td>
<td>151.5d±2.12</td>
<td>22.4d±2.91</td>
<td>196.35d±0.33</td>
<td></td>
</tr>
<tr>
<td>UOSF150</td>
<td>111.37e±0.42</td>
<td>122.00e±0.00</td>
<td>15.25e±0.13</td>
<td>151.47e±1.63</td>
<td></td>
</tr>
<tr>
<td>Fresh Seed OS</td>
<td>101.21±0.12</td>
<td>66.32±0.04</td>
<td>86.45±0.06</td>
<td>194.50±0.15</td>
<td></td>
</tr>
</tbody>
</table>

Values are means ± standard deviation. Values in the same column carrying different superscript are significantly different (P < 0.05)

Keys: DOSF 30 = defatted orange seed flour boiled for 30 min, DOSF 60 = defatted orange seed flour boiled for 60 min; DOSF 90 = defatted orange seed flour boiled for 90 min; DOSF 120 = defatted orange seed flour for 120, DOSF 150 min = defatted orange seed boiled for 150 min. UOSF 30 = defatted orange seed flour boiled for 30 min, UOSF 60 = defatted orange seed flour boiled for 60 min; UOSF 90 = defatted orange seed flour boiled for 90 min; UOSF 120 = defatted orange seed flour for 120, DOSF 150 min = Udefatted orange seed boiled for 150 min and W= Wheat (Control)
References from other crops (i.e., maize, cocoyam, water yam, and plantain). Properties of ours from orange seed ours revealed that the ours could be used in composite applications in baked products as those compared to wheat our. The debittering methods reduced the levels of antinutrients in the orange seeds ours. Physicochemical value decreased with boiling time. Defatted and undefatted orange seed ours are rich in protein, mineral, vitamin and bre when to possess instant characteristics and needs to be studied for different powdered products. However the foaming capacity, bulk density require oil absorption capability to maintain avor and improve palatability. Wettability which indicate the degree to a dried powder is likely and defatting. The WAC, OAC, LGC and wettability of the defatted and undeffatted contents increased with boiling time. Bakery products, used to substitute wheat our in food production with improved nutritional benets. The debittering methods (boiling and defatting) According to the results of these ndings, the following conclusions can be drawn; Defatted and undefatted orange seed our could be boiled for 150 min and W= Wheat (Control).

<table>
<thead>
<tr>
<th>FLOUR</th>
<th>BLEND</th>
<th>WAC (g/g)</th>
<th>OAC (g/g)</th>
<th>DISPET (S)</th>
<th>WETABILITY (%)</th>
<th>FOAM (%)</th>
<th>LGC (G)</th>
<th>BD (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEFATTED</td>
<td>W</td>
<td>1.96±0.06</td>
<td>1.58±0.02</td>
<td>70±1.12</td>
<td>42.85±0.09</td>
<td>15±0.03</td>
<td>5.0±0.00</td>
<td>0.804±0.02</td>
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<tr>
<td>DOSF30</td>
<td></td>
<td>1.99±0.02</td>
<td>1.7±0.12</td>
<td>84±0.22</td>
<td>23.90±0.12</td>
<td>5±0.06</td>
<td>15±0.00</td>
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<td>DOSF60</td>
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<td>2.19±0.03</td>
<td>3.13±0.02</td>
<td>80±0.01</td>
<td>25.96±0.10</td>
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<tr>
<td>DOSF90</td>
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<td>2.13±0.04</td>
<td>3.86±0.03</td>
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<tr>
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<td>2.42±0.02</td>
<td>3.92±0.01</td>
<td>75±0.04</td>
<td>28.52±1.22</td>
<td>5±0.05</td>
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<tr>
<td>DOSF150</td>
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<td>2.84±0.03</td>
<td>4.56±0.04</td>
<td>80±0.02</td>
<td>30.18±0.22</td>
<td>5±0.02</td>
<td>25±0.00</td>
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<tr>
<td>UNDEFATTED</td>
<td>W</td>
<td>1.96±0.06</td>
<td>1.58±0.02</td>
<td>70±1.02</td>
<td>42.85±1.09</td>
<td>15±0.02</td>
<td>5.0±0.00</td>
<td>0.804±0.01</td>
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<tr>
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<td>1.88±0.02</td>
<td>0.81±0.05</td>
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<td>4±0.09</td>
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<td>2.26±0.03</td>
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<td>18.57±0.22</td>
<td>3±0.05</td>
<td>25±0.00</td>
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</tr>
</tbody>
</table>

Values are means ± standard deviation. Values in the same column carrying different superscript are signicantly different (P < 0.05)

Keys: DOSF 30 = defatted orange seed flour boiled for 30 min, DOSF 60 = defatted orange seed flour boiled for 60 min; DOSF 90 = defatted orange seed flour boiled for 90 min; DOSF 120 = defatted orange seed flour for 120, DOSF 150 min = defatted orange seed boiled for 150 min. DOSF 30 = defatted orange seed flour boiled for 30 min, UOSF 60 = defatted orange seed flour boiled for 60 min; UOSF 90 = defatted orange seed flour boiled for 90 min; UOSF 120 = defatted orange seed flour for 120, DOSF 150 min = Udefatted orange seed boiled for 150 min and W= Wheat (Control)

Conclusion

According to the results of these ndings, the following conclusions can be drawn; Defatted and undefatted orange seed flour could be used to substitute wheat flour in food production with improved nutritional benefts. The debittering methods (boiling and defatting) increased the protein and fiber content of the orange seed flour, however, the fat content of the orange seeds flours reduced with boiling and defatting. The WAC, OAC, LGC and wettability of the defatted and undefatted contents increased with boiling time. Bakery products, require oil absorption capability to maintain flavor and improve palatability. Wettability which indicate the degree to a dried powder is likely to possess instant characteristics and needs to be studied for different powdered products, However the foaming capacity, bulk density value decreased with boiling time. Defatted and undefatted orange seed flours are rich in protein, mineral, vitamin and fibre when compared to wheat flour. The debittering methods reduced the levels of antinutrients in the orange seeds flours. Physicochemical properties of flours from orange seed flours revealed that the flours could be used in composite applications in baked products as those flours from other crops (i.e., maize, cocoyam, water yam, and plantain).

References

34. Marangoni F, Poli A (2008) The glycemic index of bread and biscuits is markedly reduced by the addition of a proprietary fiber mixture to the ingredients. Nutr Metabolism Cardiovasc Dis 18:602–605


Figures

![Orange seed processing flow chart](image)

Figure 1

Flow chart for processing of defatted orange seed flour
Orange seed
  ↓
Cleaning
  ↓
Sun drying
  ↓
Soaking
  ↓
Boiling
  ↓
Dehulling
  ↓
Winnowing
  ↓
Oven drying
  ↓
Grinding
  ↓
Orange seed flour

Figure 2

Flow chart for processing of undefatted orange seed flour