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Utilization of moringa oleifera seeds flour and starches of white yam, trifoliate yam and sweet potato in cookies

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Abstract

Native starches extracted from selected roots and tubers (white yam, trifoliate yam and sweet potato) were physically and chemically modified through heat moisture treatment and acetylation respectively while nutritious flour was processed from *Moringa oleifera* seeds. Composite flours of 85% wheat flour, 10% native/modified starch and 5% *Moringa oleifera* seed flour blends were developed for production of composite cookies. Nutritional compositions and baking properties of these composite cookies were investigated against those of control samples (i.e. 100% wheat flour cookies). Nutritionally, composite cookies were significantly ($p<0.05$) higher than control cookies while in terms of baking properties, the control cookies did not significantly ($p<0.05$) differ from composite cookies. Cookies sample NSPC (i.e. made from composite flour of 85% wheat flour: 10% native sweet potato starch: 5% *Moringa oleifera* seed flour) took lead positions in crude fat content (19.30%), protein content (13.25%), calcium content (121.95 mg/100g), iron content (3.75 mg/100g), vitamin A content (4.910 µg/g), vitamin B_1 content (0.079 mg/100g), vitamin B_2 content (0.112 mg/100g), vitamin B_3 content (0.580 mg/100g), vitamin B_6 (0.480 mg/100g) and vitamin C content (14.710 mg/100g). Though NTYC (cookies of composite flour of 85% wheat flour: 10% native trifoliate yam starch: 5% *Moringa oleifera* seed flour) and CTYC (cookies of composite flour of 85% wheat flour: 10% acetylated white yam starch: 5% *Moringa oleifera* seed flour) shared the highest moisture content of 8.20%, NTYC had highest values in ash content (2.60%) and spread factor (62.37)) and toddled in carbohydrate content (55.45%). CWYC (i.e. cookies of composite flour of 85% wheat flour: 10% acetylated white yam starch: 5% *Moringa oleifera* seed flour) had best values in storage-ability potential (i.e. lowest moisture content of 2.50%) and energy content (467.30 Kcal), but had lowest values in magnesium (57.31 mg/100g) and phosphorus content (64.18 mg/100g). The 100% wheat flour cookies (CTLC) led in carbohydrate content (63.35%), magnesium content (64.71 mg/100g) and phosphorus content (69.28 mg/100g) but lagged behind in ash content (1.70%), crude fat content (1.25%), protein content (11.75%), iron content (2.45%), vitamin A (2.250 µg/g), vitamin B_1 (0.047 mg/100g), vitamin B_2 (0.073 mg/100g), vitamin B_3 (0.250 mg/100g), vitamin B_6 (0.290 mg/100g), vitamin C (13.530 mg/100g) and spread factor (41.47). PWYC (cookies of composite flour of 85% wheat flour: 10% heat moisture treated white yam starch: 5% *Moringa oleifera* seed flour) recorded lowest values in crude fat content (17.80%) and energy value (441.30 Kcal); whereas PTYC (cookies of composite flour of 85% wheat flour: 10% heat moisture treated trifoliate yam starch: 5% *Moringa oleifera* seed flour) made lowest values in crude fibre content (1.60%) and calcium (117.31 mg/100g). NWYC (cookies of composite flour of 85% wheat flour: 10% native white yam starch: 5% *Moringa oleifera* seed flour).led in crude fibre content (1.73%) and general acceptability (8.07) while CSPC (cookies of composite flour of 85% wheat flour: 10% acetylated starch: 5% *Moringa oleifera* seed flour) scored lowest in general acceptability (6.20).

Keywords: native and modified white yam/trifoliate yam/sweet potato starches; wheat flour; *moringa oleifera* seeds; composite flour; nutritional compositions and baking properties; cookies

Introduction

Cookies are small, flat dessert treats, commonly made in variety of styles and shapes using various ingredients such as wheat flour, sugar, chocolates, peanut butter/cooking oil, nuts or dried fruits and eggs (Igbabul *et al*, 2018) [12]. According to Ayo *et al* (2010) [7] and Igbabul *et al* (2018) [12] cookies generally compose of fat (18.5%), carbohydrates (78.23%), ash (1.0%), protein (7.1%) and crude fibre (0.85%). This form of confectionery, characterized with low moisture contents and soft texture, are increasingly becoming staple snack foods due to their taste, crispness, digestibility, ready to eat, convenience and relatively stable shelf life.

Unfortunately, the exorbitant cost of importation of wheat flour (a major ingredient of cookies) into Nigeria and the poor nutritional content of wheat flour are major challenges confronting food industries in Nigeria and other tropical countries. The Nigerian Government is relentlessly supporting researches geared towards identifying, developing and promoting indigenous raw materials that could partially or totally replace wheat flour in all wheat flour based products. This commitment from Government has challenged the Food Scientists to deploy composite flour technology in production of cookies and other bakery products. By the way, in developing countries like Nigeria where the supply of some essential nutrients in our diet is inadequate to meet the rapidly growing population of citizens, supplementing wheat flour with highly nutritious materials like *Moringa oleifera* seeds flour will tremendously improve the nutritional composition of such flour-based bakery product. Of course, this is one of the potent ways of tackling malnutrition in developing countries. Composite flour is a mixture of flours/starches and other ingredients meant to replace wheat flour totally or partially in pastry or baked products (Shittu *et al*, 2007 [35]; Igbabul *et al*, 2018) [12]. Composite flour technology is rich with many advantages such as: it plays a vital role in complementing the deficiency of essential nutrients, saves hard currency; increases utilizations of local crops, promotes control of postharvest food losses, promotes high yielding local plant species and enhances overall use of domestic agriculture (Shittu *et al*, 2007 [35]; Iwe *et al*, 2014 [16]; Igbabul *et al*, 2014 [11]; Igbabul *et al*, 2018 [12]; Okereke *et al*, 2021) [25].

Many studies have investigated the use of composite flours, from cereal, pseudocereals, root and tuber crops, as a replacement to wheat flour in cookies production. Amidst the many advantages of the use of these composite flours, achievement of acceptable physical and sensory properties of the formulated cookies remains a challenge. Physical properties of cookies such as crumb hardness, weight, diameter, thickness and spread ratio are used to evaluate the physical qualities of cookies by consumers. They form part of the quality characteristics of cookies (Chinma *et al*, 2012) [9]. For instance, consumers prefer cookies of high spread ratio to the ones of low spread ratio (Chinma *et al*, 2012) [9]. The performances of these aforementioned physical properties are dependent on the ingredients, composition of the flour, mixing and baking procedure of the cookies.

Starch constituting about 65 - 85% of grain based flour is an important component of bakery products, functionally and nutritionally (Okereke *et al*, 2021) [25]. Besides, formulations of composite flours with starches show better baking responses than those with flours (Iwe *et al*, 2014) [16]. Studies have revealed that processing of starch from cereals is far more expensive than other sources like roots and tubers (Okereke, 2012 [24]; Iwe *et al*, 2014) [16]. Roots and tubers are second in importance to cereals as global sources of carbohydrates (Ugwu, 2006) [37]. The growing importance of roots and tubers come from their potentials to replace cereals, as sources of new starches and basis for processed products. Examples of roots and tubers are potatoes, sweet potatoes, beets, arrowroots, carrots, taro, cassava, cocoyam and yams (Iwe *et al*, 2014 [16]; Saranraj *et al*, 2019). Presently Nigeria is the leading world yam producer (Iwuchukwu and Okwor, 2017) [17] and the second leading producer of sweet potato globally (Udemezue, 2019) [36] but yet yams and sweet potatoes have not been fully utilized domestically and industrially (Okereke *et al*, 2021) [25]. At least expanded utilizations of yams and sweet potatoes through industrial exploitations will curb postharvest food losses threatening food security, create job opportunities and accelerate economic growth (Okereke *et al*, 2021) [25]. Therefore, the burning desire to transform these selected roots and tubers from mainly domestic food crops into key industrial crops will justify this study.

Starches from different origins have different compositional and structural properties and it is known that such variance in starches can affect the properties of cookies batter (Vatanasuchart, *et al*, 2005) [39]. Besides, the native or unmodified starches exhibit limited applications (Kavlani *et al*, 2012) [18] due to their inherent weakness of hydration, low shear stress resistance, thermo-decomposition, high retrogradation and syneresis, poor swelling and structural organization, poor processability and solubility in common organic solvents. To enhance viscosity, texture and stability among many food and non-food industrial applications, starches and their derivatives are modified by physically, chemically, enzymatically and genetically means (Kavlani *et al*, 2012) [18].

Interestingly, studies have proved that acceptable bakery products could be produced with up to the 15% level of incorporation of starch or flour (Okereke, 2012 [24]; Igbabul *et al*, 2014 [11]; Iwe *et al*, 2014) [16]. Thus, native and modified starches obtained from selected roots and tubers-white yam (*Dioscorea rotundata*), trifoliate yam (*Dioscorea dumetorum)* and sweet potato (*Ipomoea batatas*), will be blended with wheat-*Moringa oleifera* seed composite flours for the production of cookies in order to investigate their nutritional, physical and sensory properties.

Materials and Methods

Materials

Fresh tubers of white yam (*Dioscorea rotundata*), trifoliate yam (*Dioscorea dumetorum*) and roots of sweet potato (*Ipomoea batatas*) were obtained from Benue State Agricultural Development Authority (BNARDA), Makurdi, Benue State, Nigeria. Wheat flour and baking ingredients (sugar, salt, eggs, vegetable fat and baking powder) were obtained from Wurukum market while matured *Moringa oleifera* seeds were obtained from University of Agriculture farms, Makurdi, Benue State. Water used was obtained from the Department of Chemistry laboratory, Benue State University, Makurdi, Benue State.

Methods

Starch extraction: Starch was extracted from cleaned, peeled and macerated tubers using the method of Onabolu *et al* (2003) [27].

Modification of the Starches: Portions of oven dried starch from the white yam starch/trifoliate yam starch/sweet potato starch were physically and chemically modified through heat moisture treatment (HMT) and acetylation processes respectively. For heat moisture treatment, the method of Lim *et al* (2001) [22] was used. The method of Sathe and Salunkhe (1981) [32] was adopted for acetylation.

Production of *Moringa oleifera* Seed Flour: Flour from cleaned matured *Moringa oleifera* seeds was produced using the method of Bolarinwa *et al* (2017) [8].

Formulation of the Flour Blends for the Composite Flour: The wheat flour, white yam/trifoliate yam/sweet potato starch and *Moringa oleifera* seed flour were mixed in Philip blender (HR2811 model) at full speed for 5 minutes to obtain ten different flour blends labeled samples CTLF, NWYF, NTYF, NSPF, PWYF, PTYF, PSPF, CWYF, CTYF and CSPF as shown in Table 1.

Production of Cookies Samples

Ten different cookies' samples were produced and coded as

CTLC, NWYC, NTYC, NSPC, PWYC, PTYC, PSPC, CWYC, CTYC and CSPC. Sample CTLC served as 'control' and contained 100% wheat flour. Samples NWYC, NTYC, NSPC, PWYC, PTYC, PSPC, CWYC, CTYC and CSPC contained composite flour of 85% wheat flour, 10% starch and 5% *Moringa oleifera* seed flour (Chinma *et al*, 2012 [9]; Igbabul *et al*, 2018) [12] for each starch sample; and other ingredients for cookies' production as presented in Table 2. The cookies were prepared according to the method of AACC (2000) [1] with some modifications in the recipe (Igbabul *et al*, 2018) [12]. The dry ingredients (composite flour, sugar, salt and baking powder) were weighed and thoroughly mixed in a bowl by hand for 3 min. Vegetable shortening (fat) was added and mixed until uniform with enough water. The batter was then rolled out and cut with a 50 mm diameter cookie cutter. The cookies were then placed on baking trays, leaving 25 mm spaces in between and baked at 180 °C for 10 min in the baking oven. Following baking, the cookies were cooled at ambient temperature, packed in polyethylene bags and stored at 23 °C prior to subsequent analyses and sensory evaluation. The procedure is shown in Figure 1.

Table 1: Formulation of flour blends of wheat flour, starch and *Moringa oleifera* seeds flour

Ingredients			
Flour Blends	**Wheat Flour (g)**	**Starch (g) (White yam/trifoliate yam/sweet potato)**	***Moringa oleifera* Seed Flour (g)**
CTLF (Control)	100.0	0.0	0.0
NWYF	85.0	10.0	5.0
NTYF	85.0	10.0	5.0
NSPF	85.0	10.0	5.0
PWYF	85.0	10.0	5.0
PTYF	85.0	10.0	5.0
PSPF	85.0	10.0	5.0
CWYF	85.0	10.0	5.0
CTYF	85.0	10.0	5.0
CSPF	85.0	10.0	5.0

Source: Modified Iwe *et al* (2014) [16] and Bolarinwa *et al* (2017) [8]

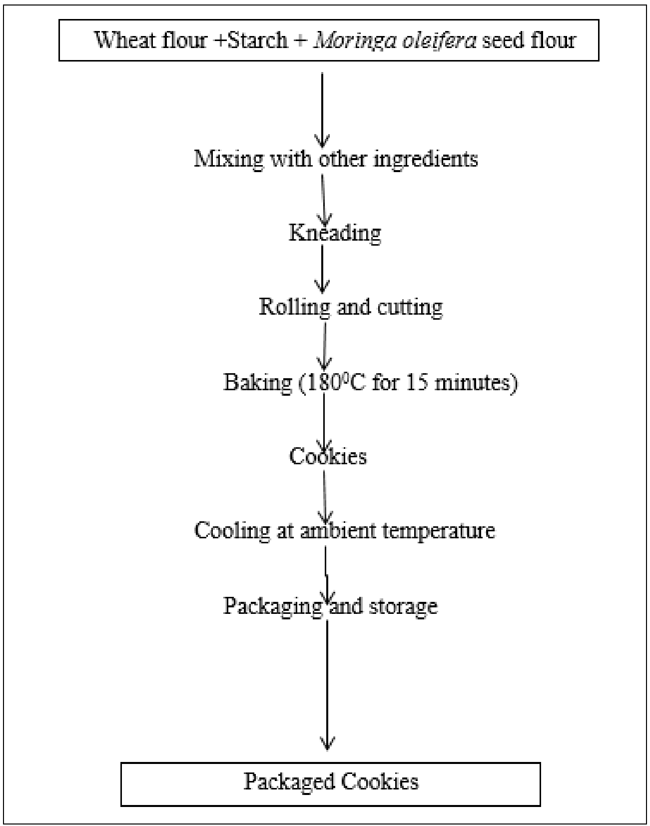
CTLF = 100% wheat flour (control)
NWYF= Flour blend (85% wheat flour: 10% native White yam starch: 5% *Moringa oleifera* seed flour)
NTYF = Flour blend (85% wheat flour: 10% native trifoliate yam native starch: 5% *Moringa oleifera* seed flour)
NSPF = Flour blend (85% wheat flour: 10% native sweet potatoe starch 5% *Moringa oleifera* seed flour)
PWYF= Flour blend (85% wheat flour: 10% physically modified (HMT) White yam starch: 5% *Moringa oleifera* seed flour)
PTYF = Flour blend (85% wheat flour: 10% physically modified (HMT) Trifoliate yam starch: 5% *Moringa oleifera* seed flour)
PSPF = Flour blend (85% wheat flour: 10% physically modified (HMT) sweet potato starch: 5% *Moringa oleifera* seed flour)
CWYF = Flour blend (85% wheat flour: 10% chemically modified (acetylated) White yam starch: 5% *Moringa oleifera* seed flour)
CTYF = Flour blend (85% wheat flour: 10% chemically modified (acetylated) trifoliate yam starch: 5% *Moringa oleifera* seed flour)
CSPF = Flour blend (85% wheat flour: 10% chemically (acetylated) sweet potato starch: 5% *Moringa oleifera* seed flour)

Table 2: Recipe formulation for production of cookies

Ingredients								
Cookies Samples	**Wheat Flour (g)**	**Starch (g) (White yam/Trifoliate/Sweet Potato)**	***Moringa oleifera* Seed Flour (g)**	**Sugar (g)**	**Fat (g)**	**Baking powder (g)**	**Salt (g)**	**Egg (ml)**
CTLC	100.0	0.0	0.0	30.0	50.0	1.67	0.5	20.0
NWYC	85.0	10.0	5.0	30.0	50.0	1.67	0.5	20.0
NTYC	85.0	10.0	5.0	30.0	50.0	1.67	0.5	20.0
NSPC	85.0	10.0	5.0	30.0	50.0	1.67	0.5	20.0
PWYC	85.0	10.0	5.0	30.0	50.0	1.67	0.5	20.0
PTYC	85.0	10.0	5.0	30.0	50.0	1.67	0.5	20.0
PSPC	85.0	10.0	5.0	30.0	50.0	1.67	0.5	20.0
CWYC	85.0	10.0	5.0	30.0	50.0	1.67	0.5	20.0
CTYC	85.0	10.0	5.0	30.0	50.0	1.67	0.50	20.0
CSPC	85.0	10.0	5.0	30.0	50.0	1.67	0.5	20.0

Source: Modified Chinma *et al* (2012) [9]; Igbabul *et al* (2018) [12]

CTLC = Cookies of 100% wheat flour (control)
NWYC = Cookies of composite flour (85% wheat flour: 10% native white yam starch: 5% *Moringa oleifera* seed flour)
NTYC = Cookies of composite flour (85% wheat flour: 10% native trifoliate yam starch: 5% *Moringa oleifera* seed flour)
NSPC = Cookies of composite flour (85% wheat flour: 10% native sweet potato starch: 5% *Moringa oleifera* seed flour)
PWYC = Cookies of composite flour (85% wheat flour: 10% HMT white yam starch: 5% *Moringa oleifera* seed flour)
PTYC = Cookies of composite flour (85% wheat flour: 10% HMT Trifoliate yam starch: 5% *Moringa oleifera* seed flour)
PSPC = Cookies of composite flour (85% wheat flour: 10% HMT sweet potato starch: 5% *Moringa oleifera* seed flour)
CWYC = Cookies of composite flour (85% wheat flour: 10% acetylated White yam starch: 5% *Moriinga oleifera* seed flour)
CTYC = Cookies of composite flour (85% wheat flour: 10% acetylated trifoliate yam starch: 5% *Moringa oleifera* seed flour)
CSPC = Cookies of composite flour (85% wheat flour: 10% acetylated sweet potato starch: 5% *Moringa oleifera* seed flour)



Source: Modified AACC (2000) [1]; Chinma *et al* (2012) [9]; Igbabul *et al*, (2018) [12]

Fig 1: Flow chart for the production of cookies

Determination of the Proximate Composition of Cookies Samples

Proximate analyses were carried out on the samples of the cookies to determine the moisture, ash, crude fibre, fat, protein and carbohydrate contents using the method outlined by the Association of Official Analytical Chemists (AOAC, 2005) [6].

Determination of Energy Value

The energy values of the cookies samples were calculated in Kcal/100g, using the Atwater Factor Method, as described by Igbabul *et al* (2018) [12].

$$E.V = (4CP + 9CF + 4C)$$

Where E.V = Energy value or Energy content measured in kilocalories (Kcal)

CP = Crude protein content

CF = Crude Fat content

C = Carbohydrate content.

Determination of Minerals (calcium, iron, magnesium and phosphorous) Contents of the Cookies Samples

Calcium, iron, magnesium and phosphorus contents of the cookies samples were determined using the method described by AOAC (2005) [6].

Determination of Vitamins (A, B_1, B_2, B_3, B_6 and C) Contents of Cookies Samples

Vitamin A contents were determined using the procedure described by Singh *et al* (2015) [34]; Vitamin B_1 (thiamine), Vitamin B_2 (riboflavin), Vitamin B_3 (niacin), contents were determined using the method described by Okwu and Ndu (2006) [26]; then the method of Kos and Surmann (2006) [19] was adopted in determination of vitamin B_6 (pyridoxine) contents while the Vitamin C (ascorbic acid) contents were determined using the method for vitamin assay (inter-science publishers, 2006) as described by Agomuo *et al* (2015) [2].

Determination of the Physical Properties of Cookies' Samples

Spread Factor of the Cookies Samples: The physical properties of the cookies were determined by the method of AACC (2000) [1] as reported by Igbabul *et al* (2018) [12]. The diameter (D) and thickness (T) of the cookies were measured by placing six cookies edge-to-edge horizontally and rotated at 90^0 angle for a duplicate reading. The thickness (T) of the cookies was measured by placing six cookies on top of each other, followed by a duplicate reading recorded by shuffling cookies. All the measurements were done in two triplicates of six cookies each and all the readings were divided by six to obtain the values per cookie. The Spread Factor (SF) was calculated according to the following formula:

$$\text{The Spread Factor (SF)} = \left(\frac{D \text{ X } CF \text{ X } 10}{5}\right)$$

Where CF = the Correction Factor at constant atmospheric pressure = 1.0 (in the present study)

Sensory Analyses of the Cookies Samples.

Samples of cookies produced were subjected to sensory analysis on a nine point hedonic scale (Iwe, 2007) [15] for consumer acceptance and preference. The quality attributes tested for cookies were appearance, aroma, taste, texture, crispness, after-mouth feel and general acceptability.

Experimental Design

The experiments were fit into a one way Analysis of variance (ANOVA). Ten (10) treatments were generated in triplicates for each experiment yielding a total of thirty (30) samples per experiment analyzed on proximate compositions, micronutrient compositions, physical and sensory properties of cookies.

Statistical Analysis

Results of all determinations were expressed as means of triplicate values. Data were subjected to one-way Analysis of Variance (ANOVA), and the means were separated using Duncan's multiple range test to determine the significant differences at 5% probability ($p<0.05$). An IBM SPSS Statistical package (version 20.0) was used for all statistical analyses.

Results and Discussion

Table 3: Proximate compositions (%) of composite cookies made from the different flour blends

Cookies sample	Moisture	Ash	Crude fat	Crude fibre	Protein	Carbohydrate	Energy value (Kcal)
CTLC	4.75±0.07^{e}	1.70±0.00^{g}	17.20±0.14^{f}	1.25±0.07	11.75±0.00^{f}	63.35±0.00^{a}	455.20±1.27^{c}
NWYC	4.00±0.00^{f}	2.00±0.07^{ef}	18.40±0.07^{cd}	1.73±0.11	12.90±0.07^{cd}	60.98±0.04^{b}	461.10±0.21^{b}
NTYC	8.20±0.14^{a}	2.60±0.07^{a}	19.00±0.14^{ab}	1.70±0.00	13.05±0.07^{bc}	55.45±0.14^{g}	445.00±0.42^{e}
NSPC	5.40±0.00^{d}	2.20±0.14^{cd}	19.30±0.64^{a}	1.65±0.07	13.25±0.07^{a}	58.20±0.92^{cd}	459.50±2.33^{b}
PWYC	8.40±0.00^{a}	1.90±0.14^{f}	17.80±0.14^{e}	1.63±0.11	12.75±0.07^{de}	57.53±0.04^{de}	441.30±0.85^{f}
PTYC	4.20±0.00^{f}	2.45±0.07^{ab}	18.40±0.28^{cd}	1.60±0.00	12.90±0.00^{cd}	60.45±0.21^{b}	459.00±1.70^{b}
PSPC	6.20±0.14^{c}	2.10±0.07^{de}	18.40±0.00^{cd}	1.65±0.21	13.10±0.07^{ab}	58.55±0.21^{c}	452.20±0.57^{d}
CWYC	2.50±0.14^{g}	1.83±0.04^{fg}	18.20±0.07^{de}	1.60±0.14	12.60±0.00^{e}	63.28±0.32^{a}	467.30±0.64^{a}
CTYC	8.20±0.00^{a}	2.30±0.07^{bc}	18.80±0.00^{abc}	1.65±0.07	12.80±0.14^{d}	56.25±0.28^{f}	445.40±0.57^{e}
CSPC	7.80±0.14^{b}	2.00±0.00^{ef}	18.60±0.14^{bcd}	1.70±0.00	12.85±0.07^{d}	57.05±0.35^{e}	447.00±0.14^{e}

Values are mean± standard deviation of triplicate determinations
Values with different superscripts within the same column are significantly different at (P<0.05).
KEY: CTLC = Cookies of 100%Wheat flour (Control)
NWYC= Cookies of composite flour (85% wheat flour: 10% native white yam starch: 5% Moringa oleifera seed flour)
NTYC = Cookies of composite flour (85% wheat flour: 10% native trifoliate yam starch: 5% Moringa oleifera seed flour)
NSPC = Cookies of composite flour (85% wheat flour: 10% native sweet potato starch: 5% Moringa oleifera seed flour)
PWYC = Cookies of composite flour (85% wheat flour: 10% physically modified white yam starch: 5% Moringa oleifera seed flour)
PTYC = Cookies of composite flour (85% wheat flour: 10% physically modified trifoliate yam starch: 5% Moringa oleifera seed flour)
PSPC = Cookies of composite flour (85% wheat flour: 10% physically modified sweet potato starch: 5% Moringa oleifera seed flour)
CWYC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)
CTYC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)
CSPC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)

Proximate Compositions of the Composite Cookies

Results of the proximate compositions of the composite cookies made from wheat flour, native/modified starch and *Moringa oleifera* seed flour blends are presented in Table 3.

The moisture contents significantly (p<0.05) ranged from 2.50 to 8.40% with sample PWYC having the highest value while sample CWYC had the lowest value. From the results, sample CWYC will be much more shelf stable than all other samples due to its very low moisture content of 2.50%. There was no significant (*p*<0.05) difference among cookies samples PWYC, NTYC and CTYC with relatively high moisture content values of 8.40%, 8.20% and 8.20% respectively. Significant (*p*<0.05) difference did not also exist between samples PTYC and NWYC with the moisture contents of 4.20% and 4.00% respectively. The differences in moisture contents of the cookies could be attributed to the interaction effects of starch sources and modification methods. However, the moisture contents of all the cookies samples were within the recommended levels for safe keeping of samples by the Standards Organisation of Nigeria (SON) as moisture content in excess of 14.00% could risk the food product to bacterial action and mold growth that bring about undesirable changes (Okereke *et al*, 2021) [25].

The ash contents of the cookies samples varied significantly between 2.60% (NTYC) to 1.70% (CTLC). Thus the incorporation of *Moringa oleifera* seeds flour in the flour blends, improved significantly (p<0.05) the ash contents of all the composite cookies but insignificantly (p<0.05) that of sample CWYC. The combined effect of starch source (white yam) and modification method (acetylation) could be responsible for the insignificant (p<0.05) difference between sample CYWC (1.83%) and control sample-CTLC (1.70%). Ash content is an index of mineral elements of foods and this result scores all the cookies well as good sources of minerals (Ayo *et al*, 2010 [7]; Igbabul *et al*, 2018) [12]. This result is in agreement with the reports of Sengev *et al* (2013) [33] and Igbabul *et al* (2018) [12] on the increased ash contents of baked products through supplementation with *Moringa oleifera* leaf powder.

The fat content was significantly (p<0.05) highest in sample NSPC with a value of 19.30% and lowest in control sample (CTLC) with a value of 17.20%. All the composite cookies had significantly (p<0.05) higher fat contents than the 100% wheat flour cookies (CTLC) as a result of contribution of fats from *Moringa oleifera* seeds flour (Warra, 2014). Functions of fats include: rich sources of energy, carriers of fat soluble vitamins (A, D, E and K), flavour improvement and retention, and even extension of shelf lives of food products. Both physical and chemical modified starches decreased the fat contents of the cookies when compared with those of their native starch counterparts irrespective of their starch sources.

Supplementation of the flour blends with *Moringa oleifera* seed flour increased the crude fibre contents of their cookies though insignificantly (p<0.05) from the control sample CTLC that had lowest value of 1.25%. Sample NTYC recorded the highest improvement in crude fibre content with a value of 1.73% while samples PTYC and CWYC recorded lowest improvement with a value of 1.60%. Studies have it that increased consumption of dietary fibre could significantly reduce the risks for obesity, type-2 diabetes, constipation, coronary heart diseases and colon cancer (Okereke *et al*, 2021) [25]. Crude fiber has little food value but provides bulk necessary for peristaltic action in the intestinal tract (Akajiaku *et al*, 2018) [4]. Physical and chemical modifications of white yam and trifoliate yam starches were observed to lead to reduced crude fibre contents of their cookies when compared to their counterparts of native starches. In the case of cookies of sweet potato starches, physical modification did not have any effect but chemical modification had increased effects (i.e from 1.65 to 1.70%).

Protein contents of the cookies varied significantly (p<0.05) between 11.75% (CTLC) to 13.25% (NSPC). From the results, significantly (p<0.05) increased protein contents of all the composite cookies in comparison with the control sample CTLC could be attributed to the incorporation of high protein *Moringa oleifera* seed flour to their flour blends (Sengev *et al*, 2013 [33]; Gopalakrishnan *et al*, 2016

[10]; Bolarinwa *et al*, 2017 [8]; Igbabul *et al*, 2018) [12]. These composite cookies, enriched with protein from *Moringa oleifera* seed flour could be recommended to consumers at risk of celiac disease due to its little or no gluten contents. Comparing the composite cookies within their starch sources, cookies of sweet potato starches maintained lead values of 13.25%, 13.10% and 12.85% in the native form, physically modified form and chemically modified form respectively. In the same trend, cookies of trifoliate yam starches seconded cookies of sweet potato starches with scores of 13.05%, 12.90% and 12.80%; while cookies of white yam starches toddled with scores of 12.90%, 12.75% and 12.60%. For modifications, cookies of physically and chemically modified starches had decreased values of protein contents when compared with those of their native starches. The result is in agreement with the reports of Sengev *et al* (2013) [33], Bolarinwa *et al* (2017) [8] and Igbabul *et al* (2018) [12] that opined that protein contents of baked goods improved after inclusion of *Moringa oleifera* seed/leaf flour in their composite flours.

There were significant (p<0.05) variations in the carbohydrate contents of the cookies which ranged from 55.45% (NTYC) to 63.35% (CTLC). Although significant (p<0.05) difference was not observed between composite cookies sample CWYC (63.28%) and control sample CTLC (63.35%), supplementation of *Moringa oleifera* seed flour and native/modified starches in the flour blends resulted in significant (p<0.05) decreased carbohydrate contents of the composite cookies. This result is in line with the report of Igbabul *et al* (2018) [12] which stated that the addition of *Moringa oleifera* leaf flour in flour blends decreased the carbohydrate contents of the composite cookies. Significant (p<0.05) difference did not exist in the following composite cookies: NWYC (60.98%) and PTYC (60.45%); PSPC (58.55%) and NSPC (58.20); NSPC (58.20%) and PWYC (57.53%). From the result, use of physically modified starches in the flour formulations led to increase in the carbohydrate contents of their cookies in comparison with those of native forms irrespective of the botanical source. These composite cookies of low carbohydrate contents and low glycemic index (Kristina and Penny, 2010 [20]; Okereke *et al*, 2021) [25] could be recommended to people of low energy levels and at risk of overweight and obesity.

Energy values of the cookies samples ranged significantly (p<0.05) from 441.30 kcal (PWYC) to 467.30 kcal (CWYC). Energy content is an important property of food. The energy our bodies use for running, talking, breathing and thinking comes from the food we eat. The variations in energy values observed can be attributed to varietal product compositions.

Table 4: Mineral contents (mg/100g) of cookies samples made from wheat flour, native/modified starch and *Moringa oleifera* flour blends

Cookies sample	Calcium	Iron	Magnesium	Phosphorus
CTLC	118.33±0.16^{e}	2.45±0.00^{g}	64.71±0.28^{a}	69.28±0.28^{a}
NWYC	119.22±0.00^{d}	3.02±0.00^{d}	58.72±0.17^{e}	65.46±0.14^{cd}
NTYC	120.09±0.00^{c}	3.42±0.00^{b}	59.38±0.11^{d}	66.45±0.30^{b}
NSPC	121.95±0.35^{a}	3.75±0.07^{a}	60.19±0.21^{b}	65.89±0.00^{c}
PWYC	117.92±0.17^{e}	2.85±0.07^{e}	57.93±0.00^{f}	64.61±0.14^{e}
PTYC	117.31±0.00^{f}	3.09±0.00^{cd}	58.72±0.00^{e}	65.87±0.10^{c}
PSPC	121.21±0.27^{b}	3.42±0.07^{b}	59.82±0.31^{bc}	65.37±0.00^{d}
CWYC	117.33±0.00^{f}	2.64±0.00^{f}	57.31±0.10^{g}	64.18±0.12^{f}
CTYC	116.75±0.35^{g}	2.82±0.09^{e}	58.59±0.00^{e}	65.46±0.00^{cd}
CSPC	120.38±0.27^{c}	3.19±0.10^{c}	59.60±0.21^{cd}	63.73±0.30^{g}

Values are mean± standard deviation of triplicate determinations
Values with different superscripts within the same column are significantly different at (P<0.05).
KEY: CTLC = Cookies of 100%Wheat flour (Control)
NWYC= Cookies of composite flour (85% wheat flour: 10% native white yam starch: 5% Moringa oleifera seed flour)
NTYC = Cookies of composite flour (85% wheat flour: 10% native trifoliate yam starch: 5% Moringa oleifera seed flour)
NSPC = Cookies of composite flour (85% wheat flour: 10% native sweet potato starch: 5% Moringa oleifera seed flour)
PWYC = Cookies of composite flour (85% wheat flour: 10% physically modified white yam starch: 5% Moringa oleifera seed flour)
PTYC = Cookies of composite flour (85% wheat flour: 10% physically modified trifoliate yam starch: 5% Moringa oleifera seed flour)
PSPC = Cookies of composite flour (85% wheat flour: 10% physically modified sweet potato starch: 5% Moringa oleifera seed flour)
CWYC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)
CTYC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)
CSPC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)

Mineral contents of the composite cookies made from the flour blends.

The results of the mineral contents of the composite cookies samples made from wheat flour, native/modified starch and *Moringa oleifera* seeds flour blends are presented in Table 4. The calcium contents significantly (p<0.05) ranged from 116.95 mg/100g (CTYC) to 121.95 mg/100g (NSPC). Composite cookies of NSPC, PSPC, CSPC, NTYC and NWYC were significantly (p<0.05) higher in calcium contents than control sample CTLC while composite cookies of CWYC, PTYC and CTYC were significantly (p<0.05) lower in values than the control sample CTLC. Among the composite cookies of the three starch sources, cookies of sweet potato starch maintained significantly (p<0.05) higher values than those of the other two starch sources. Calcium plays important roles in blood clotting, bone and teeth formation, membrane transport, nerve transmission, muscle contraction, heart rhythm and enzyme cofactor formations (Inyang *et al*, 2018 [14]; Okereke *et al*, 2021) [25]. Rickets, retarded growth, bone fractures and osteoporosis are traced to calcium deficiency (Igbabul *et al*, 2018 [12]; Okereke *et al*, 2021) [25].

Iron contents of the cookies significantly (p<0.05) increased from 2.45 mg/100g in control sample CTLC to 3.75 mg/100g in composite sample NSPC due to the additions of *Moringa oleifera* seed flour to their flour blends. All composite cookies significantly (p<0.05) had higher iron contents than control sample CTLB. Research works reveal that *Moringa oleifera* seeds are good sources of iron (Liang *et al*, 2019 [21]; Saa *et al*, 2019) [29] and this must have induced the fortification of the composite cookies with iron. Comparison of the composite cookies based on starch sources, sweet potato starches had highest iron contents while white yam starches had lowest iron contents in all the modification categories (i.e NSPC > NTYC > NWYC; PSPC > PTYC > PWYC; CSPC > CTYC > CWYC). Iron (a micro-element) is essential for the synthesis of hemoglobin of red blood cells (Inyang *et al*, 2018 [14]; Okereke *et al*, 2021) [25]. Iron deficiency in our diet leads to anemia that is characterized by weakness, dizziness and loss of weight (Inyang *et al*, 2018 [14]; Okereke *et al*, 2021) [25].

Magnesium contents of the cookies decreased significantly (p<0.05) from 64.71 mg/100g in sample CTLB (control) to 57.31 mg/100g in CWYB. The result showed negative effect of incorporation of *Moringa oleifera* seed flour and starches on the magnesium contents of the composite cookies samples. The results are in agreement with the report of Inyang *et al* (2018) [14] that indicated reduced magnesium contents in composite flour cookies. Magnesium is needed for healthy muscles and nerves metabolism. Magnesium deficiency in our diet will lead to mental, emotional and muscle disorders. Magnesium in the diet affects the metabolism of calcium, potassium and sodium (Inyang *et al*, 2018 [14]; Okereke *et al*, 2021) [25]. It is important for bone health and it is also needed as a cofactor for numerous reactions in the body. Composite cookies of sweet potato starches had the least decrement in magnesium content while composite cookies of white yam starches had highest decrement. The two types of modified starches used for the production of composite cookies had depreciated magnesium contents when compared with those of the native starches.

There were significant (p<0.05) declines in phosphorus contents from 69.28 mg/100g (CTLB) to 63.73 mg/100g (CSPC). The results conflict with the report of Sahay *et al* (2017) [30] that reported of rich content of phosphorus in *Moringa oleifera*. Phosphorus, a macro-element, is needed for formations of ATP (Adenosine triphosphate), creatine phosphate, DNA (Deoxyribonucleic acid), RNA (Ribonucleic acid), phospholipids, strong bone and cartilage, and active transport (Aja *et al*, 2013 [3]; Sahay *et al*, 2017) [30]. Besides, excess of phosphorus intake can reduce body store of calcium.

Table 5: Vitamin compositions of cookies samples made from wheat flour, native/modified starch and *Moringa oleifera* seed flour blends

Cookies Sample	Vitamin A (µg/g)	Vitamin B_1 (mg/100g)	Vitamin B_2 (mg/100g)	Vitamin B_3 (mg/100g)	Vitamin B_6 (mg/100g)	Vitamin C (mg/100g)
CTLC	$2.250±0.028^{h}$	$0.047±0.003^{g}$	$0.073±0.003^{e}$	$0.250±0.000^{h}$	$0.290±0.028^{e}$	$13.530±0.000^{e}$
NWYC	$2.840±0.042^{e}$	$0.067±0.003^{cd}$	$0.096±0.003^{c}$	$0.390±0.000^{de}$	$0.390±0.028^{bc}$	$14.650±0.071^{a}$
NTYC	$2.960±0.000^{d}$	$0.073±0.000^{b}$	$0.103±0.003^{b}$	$0.460±0.014^{c}$	$0.440±0.000^{ab}$	$14.500±0.071^{b}$
NSPC	$4.910±0.042^{a}$	$0.079±0.000^{a}$	$0.112±0.004^{a}$	$0.580±0.028^{a}$	$0.480±0.028^{a}$	$14.710±0.042^{a}$
PWYC	$2.650±0.000^{f}$	$0.059±0.000^{e}$	$0.088±0.004^{d}$	$0.330±0.000^{fg}$	$0.350±0.000^{cd}$	$14.120±0.028^{d}$
PTYC	$2.780±0.042^{e}$	$0.067±0.004^{cd}$	$0.095±0.003^{c}$	$0.410±0.028^{d}$	$0.390±0.042^{bc}$	$14.400±0.000^{c}$
PSPC	$4.630±0.000^{b}$	$0.074±0.004^{ab}$	$0.104±0.000^{b}$	$0.520±0.028^{b}$	$0.440±0.028^{ab}$	$14.650±7.071^{a}$
CWYC	$2.315±0.035^{h}$	$0.053±0.000^{f}$	$0.082±0.000^{d}$	$0.300±0.042^{g}$	$0.310±0.000^{de}$	$14.050±0.071^{d}$
CTYC	$2.520±0.000^{g}$	$0.064±0.000^{de}$	$0.087±0.001^{d}$	$0.350±0.000^{ef}$	$0.350±0.141^{cd}$	$14.320±0.028^{c}$
CSPC	$4.080±0.071^{c}$	$0.070±0.003^{bc}$	$0.098±0.001^{bc}$	$0.460±0.014^{c}$	$0.400±0.028^{bc}$	$14.500±0.000^{b}$

Values are mean± standard deviation of triplicate determinations
Values with different superscripts within the same column are significantly different at (P<0.05).
KEY: CTLC = Cookies of 100%Wheat flour (Control)
NWYC= Cookies of composite flour (85% wheat flour: 10% native white yam starch: 5% Moringa oleifera seed flour)
NTYC = Cookies of composite flour (85% wheat flour: 10% native trifoliate yam starch: 5% Moringa oleifera seed flour)
NSPC = Cookies of composite flour (85% wheat flour: 10% native sweet potato starch: 5% Moringa oleifera seed flour)
PWYC = Cookies of composite flour (85% wheat flour: 10% physically modified white yam starch: 5% Moringa oleifera seed flour)
PTYC = Cookies of composite flour (85% wheat flour: 10% physically modified trifoliate yam starch: 5% Moringa oleifera seed flour)
PSPC = Cookies of composite flour (85% wheat flour: 10% physically modified sweet potato starch: 5% Moringa oleifera seed flour)
CWYC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)
CTYC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)
CSPC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)

Vitamin Contents of the Composite Cookies Made from the Flour Blends

The results of the vitamin contents of the composite cookies samples made from wheat flour, native/modified starch and *Moringa oleifera* seed flour blends are presented in Table 5. The contents of vitamin A in the cookies significantly (p<0.05) improved from 2.250 µg/g in control sample CTLC to 4.910 µg/g in composite cookies sample NSPC due to incorporations of *Moringa oleifera* seed flours in their flour blends (Sahay *et al* 2017) [30]. Composite cookies of modified starches significantly (p<0.05) were lower in vitamin A contents than those of native starches. Comparing among the three selected root/tuber starch sources, composite cookies of sweet potato starches significantly (p<0.05) scored highest in vitamin A contents while those of white yam starches scored lowest significantly (p<0.05). Vitamin A is essential for good vision, immune reactions, growth and cell development, and balance of energy level in human body. It also promotes healthy skin, hair, nails, gums, glands, bones and teeth; stability of cell membranes and may help prevent lung cancer. Vitamin A deficiency (VAD) in the body causes retarded growth in children; and in general night blindness and skin kerantization (i.e. softening of the cornea) (Akpapunam and Igbabul, 2007 [5]; Okereke *et al*, 2021) [25]. There is high prevalence of vitamin A deficiency (VAD) in Nigeria and other African countries (Igbabul *et al*, 2014) [11] and consumption of vitamin A fortified or enriched foods is a control measure for such problem.

All the composite cookies significantly (p<0.05) differed positively from 100% wheat flour cookies in vitamin B_1

(thiamine) content because of supplementation of composite flours with *Moringa oleifera* seed flour. This result is in agreement with the report of Sahay *et al* (2017) [30]. Composite cookies NSPC had the highest value of 0.07 mg/100g in vitamin B_1 while control sample CTLC had lowest value of 0.04 mg/100g. Cookies of sweet potato starches significantly ($p<0.05$) maintained lead values while cookies of white yam starches significantly ($p<0.05$) maintained rear values in all the three categories of modifications. Comparing cookies of native starches with those of modified starches, decline in vitamin B_1 contents were observed for all cookies of modified starches. Vitamin B_1 (thiamine) is an essential nutrient for humans and its deficiency causes beriberi, which disturbs the central nervous and circulatory systems (Sahay *et al*, 2017 [30]; Okereke *et al*, 2021) [25]. Vitamin B_1 is important for maintaining a healthy metabolism. It also helps maintain normal digestion, appetite and proper nerve function (Akpapunam and Igbabul, 2007) [5]. There were significantly ($p<0.05$) increased vitamin B_2 (riboflavin) content from 0.073 mg/100g in cookies sample CTLC (control) to 0.112 mg/100g in composite cookies sample NSPC due to inclusions of *Moringa oleifera* seed flour in the flour blends. Composite cookies of sweet potato starches (NSPC, PSPC and CSPC) were significantly ($p<0.05$) highest in each modification group (i.e native, physical modification and chemical modification) while those of white yam starches were significantly ($p<0.05$) lowest. All composite cookies incorporated with modified starches had relatively low vitamin B_2 contents when compared with composite cookies incorporated with native starches for each corresponding root/tuber starch source. Vitamin B_2 is essential for energy metabolism. It also aids adrenal function, supports normal vision and helps maintain healthy skin. Dependence of people on diets deficient of vitamin B_2 are likely to make them suffer cheilosis, blurred vision and light intolerance (Okereke *et al*, 2021) [25]. The cookies samples recorded significantly ($p<0.05$) increased vitamin B_3 (niacin) contents ranging from 0.250 mg/100g (CTLC) to 0.580 mg/100g (NSPC) due to the effect of supplementation of composite cookies with *Moringa oleifera* seed flour. Composite cookies of sweet potato starches (i.e NSPC, PSPC and CSPC) were significantly ($p<0.05$) highest in all the three modification groups (i.e native, physical modification and chemical modification) while those of white yam starches (i.e NWYC, PWYC and CWYC) were significantly ($p<0.05$) lowest. This could be due the fact that sweet potato is a good source of vitamins (Igbabul *et al*, 2014 [11]; Okereke *et al*, 2021) [25]. In comparing amongst composite cookies of native starches, physically modified (HMT) starches and chemically modified (acetylated) starches; composite cookies of native starches significantly ($p<0.05$) achieved the highest values of vitamin B_3 while composite cookies of chemically modified (acetylated) starches significantly ($p<0.05$) had the lowest values for each botanical starch source. Vitamin B_3 (niacin) forms part of coenzyme used in carbohydrate, fat and protein (energy) metabolism; supports health of skin, nervous system and digestive system. Also high (pharmacological) doses of vitamin B_3 intake may control cholesterol levels. Intake of foods fortified with vitamin B_3 can reduce deficiency symptoms such as glossitis, skin eruptions, nausea, diarrhea, nervous disorders, anorexia and pellagra.

Significant ($p<0.05$) increase in vitamin B_6 (pyridoxine) contents of the cookies samples were observed from 0.290 mg/100g in CTLC (control sample) to 0.480 mg/100g in composite cookies NSPC. The significant ($p<0.05$) improvements in vitamin B_6 contents of all the composite cookies from that of the control cookies sample (CTLC) is traceable to the incorporations of *Moringa oleifera* seed flours to their flour blends. Comparing among the three selected root/tuber starch sources, composite cookies of sweet potato starches scored highest in vitamin B_6 contents while those of white yam starches scored lowest due to the fact that sweet potatoes are good sources of vitamin B_6 (Igbabul *et al*, 2014 [11]; Okereke *et al*, 2021) [25]. In comparing amongst composite cookies of native starches, physically modified (HMT) starches and chemically modified (acetylated) starches; composite cookies of native starches attained the highest values of vitamin B_3 while composite cookies of chemically modified (acetylated) starches had the lowest values for each botanical starch source. Vitamin B_6 (pyridoxine) forms part of a coenzyme that helps the body synthesize non-essential amino acids and red blood cells; also plays significant role in protein and carbohydrate metabolism and also supports normal nerve function.

The vitamin C (ascorbic acid) contents of the cookies significantly ($p<0.05$) ranged from 13.530 mg/100g in sample CTLC to 14.710 mg/100g in composite cookies sample NSPC. The significant ($p<0.05$) improvements in vitamin C contents of all composite cookies from that of the 100% wheat flour cookies (CTLC) observed, is attributable to the incorporations of *Moringa oleifera* seed flour in their flour blends (Valdez-Solana *et al*, 2015 [38]; Mgbemema and Obodo, 2016 [23]; Igwilo *et al*, 2017 [13]; Igbabul *et al*, 2018 [12]; Liang *et al*, 2019 [21]; Saa *et al*, 2019) [29]. This result is in agreement with the report of Sahay *et al* (2017) [30] and Igbabul *et al* (2018) [12] that reported *Moringa oleifera* as rich source of vitamin C. There were no significant ($p<0.05$) differences among these best performed composite cookies- NSPC, NWYC and PSPC that had values of 14.710 mg/100g, 14.650 mg/100g and 14.650 mg/100g respectively. Vitamin C (ascorbic acid) is a water-soluble vitamin that is essential in collagen formation and maintenance (strengthens blood vessels, forms scar tissue, is a matrix for bone growth); for healthy gums; prevention of atherosclerosis; serving as key antioxidant; boosting body immunity; promotion of wound healing and improving absorption of iron. Vitamin C deficiency symptoms include scurvy, sore gums and high bruising tendencies (Okereke *et al*, 2021) [25] which can be controlled through improved intake of vitamin C fortified foods like these composite cookies.

Table 6: Physical properties of cookies samples made from wheat flour, native/modified starch and *Moringa oleifera* seeds flour blends

Cookies sample	Diameter (cm)	Thickness (cm)	Spread Ratio	Spread Factor
CTLC	4.18 ± 0.15^{e}	1.01 ± 0.04^{a}	4.15 ± 0.13^{b}	41.47 ± 1.33^{b}
NWYC	3.68 ± 0.15^{h}	0.68 ± 0.01^{d}	5.41 ± 0.06^{a}	54.07 ± 0.55^{a}
NTYC	4.18 ± 0.15^{e}	0.67 ± 0.02^{d}	6.24 ± 0.17^{a}	62.37 ± 1.65^{a}

NSPC	4.96±0.02[a]	0.93±0.03[b]	5.34±0.15[ab]	53.37±1.50[ab]
PWYC	4.84±0.04[b]	0.97±0.02[ab]	4.99±0.07[ab]	49.93±0.65[ab]
PTYC	4.18±0.30[e]	0.68±0.03[d]	6.12±0.18[a]	61.23±1.82[a]
PSPC	4.67±0.03[c]	0.69±0.03[d]	5.51±2.07[a]	55.07±20.74[a]
CWYC	3.87±0.15[g]	0.67±0.03[d]	5.75±0.03[a]	57.50±0.27[a]
CTYC	4.52±0.03[d]	0.74±0.03[c]	6.11±0.21[a]	61.10±2.05[a]
CSPC	3.98±0.08[f]	0.68±0.03[d]	5.83±0.11[a]	58.30±1.14[a]

Values are mean± standard deviation of triplicate determinations
Values with different superscripts within the same column are significantly different at (P<0.05).
KEY: CTLC = Cookies of 100%Wheat flour (Control)
NWYC= Cookies of composite flour (85% wheat flour: 10% native white yam starch: 5% Moringa oleifera seed flour)
NTYC = Cookies of composite flour (85% wheat flour: 10% native trifoliate yam starch: 5% Moringa oleifera seed flour)
NSPC = Cookies of composite flour (85% wheat flour: 10% native sweet potato starch: 5% Moringa oleifera seed flour)
PWYC = Cookies of composite flour (85% wheat flour: 10% physically modified white yam starch: 5% Moringa oleifera seed flour)
PTYC = Cookies of composite flour (85% wheat flour: 10% physically modified trifoliate yam starch: 5% Moringa oleifera seed flour)
PSPC = Cookies of composite flour (85% wheat flour: 10% physically modified sweet potato starch: 5% Moringa oleifera seed flour)
CWYC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)
CTYC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)
CSPC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)

Physical Properties of the Composite Cookies Made from the Flour Blends

The results of the physical properties of the composite cookies samples made from wheat flour, native/modified starch and *Moringa oleifera* seed flour blends are presented in Table 6. The diameters of the cookies produced, significantly (p<0.05) varied between 3.68 cm in sample NWYC and 4.96 cm in sample NSPC. Composite cookies samples of NSPC (4.96 cm), PWYC (4.84 cm), PSPC (4.67 cm) and CTYC (4.52 cm) were significantly higher than that of the control sample (4.18 cm) due to increased hydrophilic sites of the starch granules of the non-wheat flours leading to moisture absorption and subsequent diameter increase (Opara *et al*, 2013 [28]; Igbabul *et al*, 2018) [12]. Composite cookies samples of CSPC (3.98 cm), CWYC (3.87cm) and NWYC (3.68 cm) had diameters significantly (p<0.05) lower than the diameter of the control sample (CTLC) due the properties of their constituent starch fractions. Composite cookies samples NTYC (4.18 cm) and PTYC (4.18 cm) did not significantly (p<0.05) differ from control sample (CTLC) in diameter. The thickness of the cookies significantly (p<0.05) decreased from 1.01 cm in control cookies sample (CTLC) to 0.67 cm in composite cookies samples (NTYC and CWYC). The decreased thicknesses of the composite cookies from that of control cookies is due to the substitution effects of wheat flour with non-wheat flours (i.e native/modified starches and *Moringa oleifera* seed flour). For example, the starches added to the flour blends were of different botanical sources and/or modification treatments and thus could have imparted different effects on the cookies due to their varying properties and behaviours.

The spread ratio or spread factor of the cookies significantly (p<0.05) increased from 4.15 (or 41.47) in control sample to 6.24 (or 62.37) in composite cookies NTYC. All composite cookies had scores higher than that of control sample. This is attributable to the effects of non-wheat flour fractions of the flour blends on the composite cookies. The increased spread ratio or factor observed could be traced further to the increased number of hydrophilic sites in the dough leading to increased water absorption and swelling index (Igbabul *et al*, 2018) [12]. For instance, modifications of starch could have degraded the starch macromolecules making it more hydrophilic, leading to decreased viscosity. The decrease in viscosity increases spread factor and reduces thickness of cookies. Cookies of high spread factors are in higher in demand than those of low spread factors (Opara *et al*, 2013 [28]; Inyang *et al*, 2018) [14].

Table 7: Sensory scores for cookies made from wheat flour, native/modified starches and *Moringa oleifera* seeds flour blends

Cookies Sample	Appearance	Aroma	Taste	Texture	Crispness	After-mouth Feel	General Acceptability
CTLC	7.40±1.72[ab]	7.20±1.74[ab]	7.60±1.50[a]	8.00±0.00[ab]	5.87±1.51[e]	7.13±2.00[a]	7.60±1.60[ab]
NWYC	8.20±0.68[a]	7.47±0.64[a]	7.60±1.45[a]	8.40±0.83[a]	7.00±2.24[cd]	6.73±1.95[a]	8.07±0.96[a]
NTYC	7.47±1.64[ab]	7.07±1.62[ab]	7.07±1.91[ab]	4.60±2.41[e]	6.53±1.69[de]	6.67±1.92[a]	6.93±1.98[ab]
NSPC	7.20±1.21[ab]	7.20±1.61[ab]	6.67±1.45[ab]	7.00±0.76[cd]	8.80±0.41[a]	6.53±1.30[ab]	7.20±1.61[ab]
PWYC	6.73±1.79[b]	6.13±1.55[bc]	6.13±1.41[ab]	7.73±0.46[abc]	5.80±1.57[e]	5.87±1.36[ab]	6.47±2.10[ab]
PTYC	7.00±1.56[ab]	7.40±1.18[a]	7.53±1.41[a]	8.00±0.76[ab]	8.80±0.41[a]	6.93±1.91[a]	6.80±1.86[ab]
PSPC	6.73±1.83[b]	5.80±1.93[c]	6.07±1.94[b]	8.27±0.46[a]	7.73±0.46[bc]	5.00±2.24[b]	6.27±2.38[b]
CWYC	7.73±1.39[ab]	6.87±1.30[abc]	7.07±1.91[ab]	7.73±1.16[abc]	8.27±0.88[cd]	6.87±1.89[a]	7.07±2.52[ab]
CTYC	7.20±1.42[ab]	6.47±1.36[abc]	6.27±2.34[ab]	7.27±0.46[bc]	8.00±0.76[ab]	5.87±2.39[ab]	6.33±2.41[b]
CSPC	7.00±1.73[ab]	6.53±1.19[abc]	6.47±1.73[ab]	6.47±0.52[d]	7.93±1.28[abc]	6.20±1.95[ab]	6.20±1.86[b]

Values are mean± standard deviation of triplicate determinations
Values with different superscripts within the same column are significantly different at (P<0.05).
KEY: CTLC = Cookies of 100%Wheat flour (Control)
NWYC= Cookies of composite flour (85% wheat flour: 10% native white yam starch: 5% Moringa oleifera seed flour)
NTYC = Cookies of composite flour (85% wheat flour: 10% native trifoliate yam starch: 5% Moringa oleifera seed flour)
NSPC = Cookies of composite flour (85% wheat flour: 10% native sweet potato starch: 5% Moringa oleifera seed flour)
PWYC = Cookies of composite flour (85% wheat flour: 10% physically modified white yam starch: 5% Moringa oleifera seed flour)
PTYC = Cookies of composite flour (85% wheat flour: 10% physically modified trifoliate yam starch: 5% Moringa oleifera seed flour)
PSPC = Cookies of composite flour (85% wheat flour: 10% physically modified sweet potato starch: 5% Moringa oleifera seed flour)
CWYC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)
CTYC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)
CSPC = Cookies of composite flour (85% wheat flour: 10% chemically modified white yam starch: 5% Moringa oleifera seed flour)

Sensory Attributes of the Composite Cookies Samples Made from Flour Blends.

The results of the scores of sensory attributes of the composite cookies samples made from wheat flour, native/modified starch and *Moringa oleifera* seed flour blends are presented in Table 7.

Appearance attributes of the cookies significantly (p<0.05) ranged from 6.73 in both PWYC and PSPC to 8.20 in NWYC. No significant (p<0.05) difference was observed between control sample (CTLC) and any of the composite cookies. This indicated that additions of *Moringa oleifera* seed flour and native/modified starch in the various flour blends of the composite cookies had no reject effects on the appearance attributes of the composite cookies. Interestingly, samples NWYC (8.20), CWYC (7.73) and NTYC (7.47) performed insignificantly (p<0.05) better than the control sample CTLC (7.40).

Sensory scores on the aroma of the cookies were observed to significantly (p<0.05) range from 5.80 in PSPC to 7.47 in NWYC. Sensory score for the aroma of the control sample (CTLC) did not significantly (p<0.05) differ from those of all the composite cookies apart from that of PSPC. Composite cookies samples NWYC and PTYC were ranked the best in aroma with scores of 7.47 and 7.40 respectively while PSPC got the lowest score of 5.80.

Cookies sample PSPC with the lowest taste score of 6.07 remained the only composite cookies sample that significantly (p<0.05) differed from the control sample (7.60) due to inclusions of *Moringa oleifera* seed flour and native/modified starch in their flour blends. However, none of the composite cookies was disliked by the panelists.

Sensory attribute of texture of the cookies significantly (p<0.05) varied between 4.60 in NTYC to 8.40 in NWYC. Sensory responses gathered, did not place any significant (p<0.05) difference between control sample CTLC (8.00) and composite cookies NWYC (8.40), PSPC (8.27), PTYC (8.00), PWYC (7.73), CWYC (7.73) and CTYC (7.27). Control sample (CTLC) with a score of 8.00 was significantly (p<0.05) preferred to composite cookies NTYC (4.60), CSPC (6.47) and NSPC (7.00). For cookies of both trifoliate yam and sweet potato starches, significant (p<0.05) improvements in texture were observed in cookies of their physically modified starches when compared to those of their native starches [i.e. PTYC (8.00) > NTYC (4.60), PSPC (8.27) > NSPC (7.00)]. Chemical modification only improved significantly (p<0.05) the texture of composite cookies of native starch of trifoliate yam [i.e. CTYC (7.27) > NTYC (4.60)].

The crispness of the composite cookies NSPC and PTYC were significantly (p<0/05) ranked highest with a common score of 8.80 while PWYC significantly (p<0.05) had lowest score of 5.80. This could be attributable to the low moisture contents of NSPC and PTYC (Table 3); and high moisture content of PWYC (Table 7). According to Wade (1988) and Sengev *et al* (2015) [33] high moisture content leads to loss of crispness and vice versa. Surprisingly, except sample PWYC, every other composite cookie performed better than control sample (CTLC) in crispness.

Sensory scores for the after-mouth feel of the cookies ranged significantly (p<0.05) from 5.00 in composite cookie PSPC to 7.13 in control sample CTLC. The results revealed that apart from sample PSPC, control sample (CTLC) did not significantly (p<0.05) differ from any of the composite cookies due to incorporations of *Moringa oleifera* seed flours and native/modified starches in their flour blends.

General acceptability scores for the cookies significantly (p<0.05) ranged from 6.20 in CSPC to 8.07 in NWYC. There was no significant (p<0.05) difference between control sample (CTLC) and any of the composite cookies produced with the incorporations of *Moringa oleifera* seed flour and native/modified starch. All the composite cookies were generally accepted by the panelists showing that composite cookies made from 85% wheat flour, 10% native/modified starch of root/tuber sources and 5% *Moringa oleifera* seed flour blends will not have any defective effect on their sensory acceptability.

Conclusion

Native, physically modified (HMT) and chemically modified (acetylated) starches from white yam, trifoliate yam and sweet potato were developed and utilized in wheat-*Moringa oleifera* seeds flour based cookies which were acceptable, nutritious and shelf-stable. The supplementation of the wheat flour-native/modified starch flour blends with *Moringa oleifera* seeds flour significantly (p<0.05) improved the nutritional qualities of the composite cookies made from them while the different native/modified starches incorporated, significantly (p<0.05) exhibited suitable baking potentials for composite flour technology in bakery products.

The development and utilizations of these starches from these roots and tubers will tremendously: curtail the huge post-harvest food losses that jeopardize food security; reduce depletion of foreign exchange reserve traceable to huge importation of wheat flour; and also promote the commercial and industrial exploitations of these local roots and tubers, as well as create employment opportunities and boost the economy of Nigeria. In addition, supplementation of wheat flour with *Moringa oleifera* seeds flour will complement the deficiency in essential nutrients, combat malnutrition and health concerns resulting from excessive consumption of wheat flour products and of course make these functional foods affordable to Nigerians.

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