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Investigation of physicochemical and textural properties of sandwich bread incorporating defatted dehydrated coconut flour

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Abstract
Bread is most consumed food in the world. Sandwich bread has soft crumb, crispy crusts and square shape and contains gluten protein, starch, and less fibre. At present consumers demand low gluten and high fibre bread. Therefore, this study was conducted to investigate potential of defatted dehydrated coconut flour (DDCF) as a gluten-free and high fibre ingredient to substitute for wheat flour (WF) and to determine correct level of substitution for an accepted formulation to produce sandwich bread. Comparison of physicochemical properties of the DDCF and WF significant differences of fat, protein, crude fibre and carbohydrates contents, water and oil absorptions, and hygroscopicity were observed ($p < 0.05$) between two types of flours. Six different treatments of composite flours of DDCF and WF were arranged in complete randomized design with three replicates. Results from flour mixing properties showed that the combinations belonged to strong flour category. Textural analysis of sandwich bread indicated that 5–10% DDCF incorporated sandwich breads were significantly similar to sandwich bread with 100% WF and sandwich bread incorporated with DDCF contained high fibre and low protein and carbohydrates compared to sandwich bread made with 100% WF ($p > 0.05$). Therefore, results of this study revealed that 5–10% DDCF incorporation to wheat flour is recommended to prepare nutritious sandwich bread with low gluten protein, high fibre and less carbohydrates compared to 100% wheat flour sandwich bread.

Keywords Sandwich bread · Coconut flour · Farinograph analysis · Textural properties · High fibre · Proximate composition

1 Introduction

Bread is considered as a highly consumed food in all parts of the world. The refined wheat flour is the main ingredient used for bread. The bread made with wheat flour is popular due to soft crumbs, crispy crusts, appealing taste, light colour and the volume [1]. The quality characteristics of wheat grains and flour making process have contributed to the excellent properties of bread [2]. Bread made from wheat flour has less fibre, high gluten- protein and high starch content. Consumers look for non-gluten flour for making bread, pizza and roti (unleavened bread). However, 100% non-gluten flour based bread are not practically possible due to poor physicochemical characteristics. This has been observed by researchers and higher percentages of non-wheat flour contributed quality issues in texture and appearance [3–5]. Cassava [3], bread fruit, banana [4], chestnut and coconut [5] are some of the non-gluten flours which have been partially substituted for wheat flour for development of low gluten bread.

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Coconut kernel, the edible part, contains fat greater than 40% and hence is widely used as a raw material for edible oil production. Coconut kernel is dehydrated, and then oil is expelled mechanically and defatted dehydrated coconut kernel (DDCK) is obtained as a by-product which has potential application as a non- cereal flour. World annual coconut oil production is around 3.51–3.63 million metric tons [6] and it generates around 2.4 million metric tons of defatted coconut meal which has potential application of food industry. The DDCK is ground into a flour for using substitute for wheat flour. This ground DDCK is referred to as defatted desiccated coconut flour (DDCF) and it contains moisture 4.20%, ash 8.2%, protein 12.6%, fibre 13.0%, fat 9.2%, and carbohydrates 52.1% [7] while wheat flour contains moisture 9.76%, ash 0.51%, protein 9.9%, fibre 0.5%, fat 0.87% and carbohydrates 78.46% [8]. Coconut kernel contains protein fractions albumin and globulin and it is non-gluten ingredient [9]. DDCF has shown potential prebiotic properties as reported by [10]. Crude polysaccharides in DDCF are insoluble carbohydrates 46.0 ± 3.1% and soluble carbohydrates 9.2 ± 0.1% [11]. The unique properties of insoluble and soluble carbohydrates in DDCF can be added to the bread by incorporating to wheat flour in various food formulations.

Biscuits with good organoleptic properties were produced by incorporating 30% DDCF and 70% wheat flour and the biscuits exhibited predicted glycemic index of 61 [12]. Coconut flour was incorporated to wheat flour to develop a suitable formulation for a cake [13]. The formulation included increased level of 10–30% coconut flour into 90–70% wheat flour in different treatment and sugar and bakery powder were also changed to obtain good organoleptic and physicochemical properties. According [13], significant changes in volume, weight, specific volume and moisture contents of the cakes were observed and 30% incorporation gave poor quality cakes while improved quality of the cakes was observed when sugar and bakery powder were increased. Further, Coconut flour (up to 25%) was incorporated to wheat flour to develop a formulation for muffin and increased incorporations levels of coconut flour exhibited higher organoleptic properties [14]. According to [15], 10% coconut flour incorporation to produce regular bread gave higher acceptability compared to the incorporation of coconut flour 20% and 30%. The increase in coconut flour in wheat flour bread caused to reduce the bread volume and increase harness which are not acceptable qualities of bread.

Sandwich bread has a soft crumb compared to the regular one and is popular among bread consumers. It typically comes in a rectangular loaf, pre-sliced for convenience. The uniform size of the slices makes it ideal for stacking fillings in sandwiches.

Sandwich bread is widely consumed across the globe, making it an ideal candidate for incorporating desirable properties of DDCF, such as high levels of non-starch polysaccharides [11] and high gluten free protein content. As global trend of gluten free flour market is expected to increase at a CAGR of 8.1% during 2021–2018 from $ 5.6 billion in 2020, there is an increase market potential for coconut flour as it is included in gluten free flour category [16]. Keeping with this trend aim of this study was to develop a formulation for DDCF-enriched sandwich bread with characteristics comparable to those of traditional 100% wheat flour sandwich bread. Additionally, the study aimed evaluating physico-chemical and textural properties of the sandwich bread and to identify most promising sandwich bread formulation.

2 Materials and methods

2.1 Materials

Coconut: The coconuts (*Cocos nucifera* L.) were harvested and collected from Bandirippuwa estate of Coconut Research Institute, Lunuwila Sri Lanka.

Defatted desiccated coconut flour: Fully mature coconuts of tall variety obtained from Bandirippuwa estate of Research Institute of Sri Lanka were stored for 3 weeks in shade. The nuts were de-husked and de-shelled, and the testa of the fresh kernels was peeled off. The white kernels were washed and then disintegrated and were dehydrated at 60 °C until the moisture content was about 3%. The oil was extracted using a cold press oil expeller (Udaya industries, Sri Lanka) to obtain defatted dehydrated coconut kernels, which were then ground into a fine powder (IKA M20 Universal grinder) to produce defatted dehydrated coconut flour (DDCF). Particle separation of DDCF was carried out using standard sieves (BS Standard) of 500 µm and 150 µm. The sieves were stacked 500 µm on top followed by 150 µm and receiving pan respectively. The sieves were assembled in sieve shaker. DDCF (500 g) was places on top 500 µm sieve and closed with lid and were shaken for 30 min. The remaining portion on 500 µm sieve were the DDCF with particle sizes > 500 µm and the those on 150 µm sieve were between 500 µm and 150 µm and those on the receiving pan were < 150 µm. The separated flour were packed in polythene bags and stored in refrigerated condition.

Ingredient for bread making: The premium grade wheat flour (Seven star, Baker's flour), white granulated sugar (Star gold brand, India), yeast (Mauripan brand) salt (iodized salt, Lanka salt limited, Sri Lanka) and, bread compound (East West Marketing, Sri Lanka) were purchased from Sampath bakery in Haldaduwana, Dankotuwa of Sri Lanka.

2.2 Methods

2.2.1 Determination of physical properties of flour

2.2.1.1 Water absorption and oil absorption capacity The oil and water absorption capacities of the flour samples were determined as the percentage of water or oil bound per gram of the flour [17]. One gram of flour was placed in a graduated centrifuge tube and 10 ml of distilled water / soya bean oil were added. The contents were mixed by shaking and were left at room temperature for 30 min and then centrifuged at 3000 rpm for 30 min. The volume of free water was then measured directly from the calibration of the centrifuged tube.

The hygroscopicity of the flour sample was determined using the modified version of [17]. The modifications were made to the relative humidity and temperature, which were modified as 74% relative humidity using NaCl in a desiccator at 28 °C. After seven days of storage under these conditions, the percentage of moisture absorbed by the flour samples was measured.

2.2.1.2 Proximate composition of composite flour Proximate composition of wheat flour, DDCF and sandwich breads were determined using Standard methods. Moisture, protein (Kjeldahl method) and ash contents of flour samples were determined using AOAC (2016) [18]. Fat (Randle fat extractor protocol: 945.16) and the crude fiber contents (Fibertec apparatus Velp, Scientific, Italy) according to ISO 6865:2000 [19]. Carbohydrate content was calculated using equation provided by the Food and Agriculture Organization [20].

2.2.1.3 Gluten content of flour combinations Wheat flour (25.0 g) was placed in a plastic bowl and mixed with 15 ml of water to obtain a dough ball. The ball was immersed in water for one hour followed by washing by kneading in gentle stream of water over a fine sieve until washing water was clear. The cohesive mass remined on the sieve was press to remove excess water and placed on previously weighed dry petri dish and was dried for 24 h until constant weight was obtained. The percentage of dry gluten is reported. The procedure was reported for DDCF of different particle sizes.

2.2.1.4 Preparation of sandwich bread Ingredients for making control sandwich bread (T0) were wheat flour (400 g), sugar (16 g), yeast (4 g), salt (8 g), bread compound-palm oil (16 g) and water (236 g). The dry ingredients were combined in a dough mixer (Spiral mixer, Commercial kitchen, Sri Lanka) with 3 speeds (speed one: 62 r/minute, speed two: 115 r/minute and speed three: 310 r/minute) and mixed for one minute at speed one, followed by addition of water followed by mixing for three minutes at speed 2. Bread compound was added and mixed for 10 min at speed 3 followed by mixing for 3 min at speed 2. The resulting dough was made into a round shape and allowed to rest for 10 min. Then 520 g of the dough was reshaped and allowed to rest for another 10 min before being hand-pressed to release any air and formed into the desired shape. The dough was then placed into a mould of $19.5 \times 10 \times 10$ cm^3 and partially covered with lid and was allowed to rest until the dough had risen to the top of the mould. Time taken for dough rising time was noted. At this stage, the lid was closed completely and was baked in an oven preheated at 225 °C for 5–10 min. The sandwich bread was baked for 45 min at 225 °C. The sandwich bread was removed from oven and let it cool to room temperature and cut into slices of 5 mm thickness.

The above procedure was repeated for treatments T1 through T5, using varying amounts of wheat flour (380 g, 360 g, 340 g, 320 g, and 300 g) combined with 20 g, 40 g, 60 g, 80 g, and 100 g of defatted desiccated coconut flour (DDCF) of particle size between 500 µm-150 µm, respectively. All other ingredients, except water, remained consistent with the control. Water was added gradually, measuring the volume required to achieve the correct dough consistency. Mixing times, resting durations, and dough rising times for each treatment which were adjusted to achieve dough properties.

2.2.1.5 Determination of mixing properties of flour Mixing properties of the flour combinations of T0, T1, T2, T3, T4 and T5 were determined. Properties of water absorption, arrival time, dough development time, departure time, stability time and mixing tolerance index were determined using Farinograph (BRABENDER OHS, DUIDBURG, Germany) using constant flour weight procedure [21]. Moisture contents of the samples were determined using oven methods. On 14%

moisture basis, 291.5, 291.0, 290.4, 290.0, 289.4, 288.8 g were weighed from T0, T1, T2, T3, T4 and T5 respectively for analysing the mixing properties of flour using [21].

2.2.1.6 Determination of chromomeric parameters of the bread Colour of the bread was determined using Chroma meter (B8205231, Japan) and data were expressed as CIELAB scale in terms of L* (lightness), a* (redness) and b* (yellowness) values.

2.2.1.7 Textural properties of the bread Texture profile of the bread samples was analyzed by CT3 Texture Analyzer (Brookfield, USA) with Texture Pro CT.V1.9 Built 35 software. The parameters of hardness, adhesiveness, stringiness and fracturability were determined using the probe of TA 39. A slice of 40 mm thickness was cut and then slices of 10 mm on each side were removed. The compression test was performed using a cylindrical probe with a 75 mm base diameter, spaced by an interval of 5 s between cycles. A 30 kg load cell was used and the test and post test speeds were 1 mm/s. Then 1st withdrawal was allowed and second compression test was conducted. The second withdrawal was allowed. Fracturability, hardness, cohesiveness, springiness, gumminess and chewiness were calculated using the in-built software of the equipment. The analysis was conducted in four replicates and mean and standard deviation calculated.

2.3 Statistical analysis

All experiments were done in complete randomized design with 3 replicates and statistical analyses were carried out using Minitab, 2015 version. mean and standard deviations were calculated. Significance differences were determined using one way ANOVA and mean separation was done using Duncan's Multiple Range Test at $p < 0.05$.

3 Results

3.1 Physicochemical properties of defatted desiccated coconut flour

Coconut flour was separated into three ranges of particle sizes using standard sieves (greater than 500 µm, 500–150 µm and less than 150 µm) to see the effects of particle sizes on physicochemical properties. The proximate composition and physicochemical characteristics of the coconut flour with different particle sizes and wheat flour are shown in Table 1.

3.1.1 Proximate composition

The results in Table 1 indicate significant differences in moisture content between DDCF samples of varying particle sizes and wheat flour ($p < 0.05$). Wheat flour exhibited the highest moisture content at 11.50 ± 0.25%. In contrast, the moisture content of DDCF samples ranged from 6.97 ± 0.17% to 8.17 ± 0.22%, with significant differences among the various particle sizes.

Fat content remained relatively consistent across the different particle sizes of DDCF, ranging from 9.58 ± 0.31% to 9.81 ± 0.04%. Notably, the fat content of DDCF was significantly higher than that of wheat flour, which had a fat content of 1.18 ± 0.15% ($p < 0.05$. Regarding ash content, wheat flour had 0.64 ± 0.04% which was significantly lower than the ash content of the DDCF samples ($p < 0.05$). The ash content of DDCF decreased significantly from 6.38 ± 0.02% to 6.15 ± 0.02% as particle size decreased.

Protein content, a crucial nutrient, also showed significant differences between wheat flour and the various DDCF particle sizes ($p < 0.05$). DDCF demonstrated a significantly higher protein content (19.68 ± 0.70% to 19.90 ± 0.42%) compared to wheat flour (11.09 ± 0.31%), with no significant variation in protein content among the different DDCF particle sizes. The dry gluten content of wheat flour was 8.70 ± 0.20% while the DDCF of different particle sizes did not have detectable gluten contents.

Crude fiber content was notably higher in DDCF, ranging from 13.68 ± 0.43% to 19.09 ± 1.45%, compared to the crude fibre content of wheat flour of 0.53%. DDCF with particle sizes greater than 500 µm had the highest crude fiber content. Conversely, wheat flour contained a significantly higher carbohydrate content (75.09 ± 0.69%) than DDCF, which ranged from 38.16 ± 1.68% to 41.92 ± 0.98%. No significant variation in carbohydrate content was observed among the different particle sizes of DDCF.

Table 1 Physicochemical properties defatted desiccated coconut flour and wheat flour

Parameter	Defatted dehydrated coconut flour with different particle sizes			Wheat flour
	> 500 µm	500–150 µm	< 150 µm	
Moisture %	6.97 ± 0.17[d]	8.76 ± 0.10[b]	8.17 ± 0.22[c]	11.50 ± 0.25[a]
Fat %	9.58 ± 0.31[a]	9.74 ± 0.16[a]	9.81 ± 0.04[a]	1.18 ± 0.15[b]
Ash %	6.38 ± 0.02[a]	6.21 ± 0.03[b]	6.15 ± 0.02[b]	0.64 ± 0.04[c]
Protein %	19.81 ± 0.23[a]	19.68 ± 0.71[a]	19.90 ± 0.42[a]	11.09 ± 0.31[b]
Crude fibre %	19.09 ± 1.45[a]	13.68 ± 0.43[b]	15.81 ± 2.12[a,b]	0.53 ± 0.00[c]
Carbohydrates %	38.16 ± 1.68[b]	41.92 ± 0.98[b]	40.15 ± 2.12[b]	75.09 ± 0.69[a]
Swelling capacity (ml)	8.33 ± 1.15[b]	7.10 ± 0.00[b]	8.33 ± 1.15[b]	17.33 ± 0.58[a]
Oil absorption (ml/g)	1.03 ± 0.23[b]	1.07 ± 0.12[b]	1.03 ± 0.06[b]	1.40 ± 0.00[a]
Water absorption ml/g	10.07 ± 0.23[c]	10.37 ± 0.06[c]	11.73 ± 0.23[b]	9.00 ± 0.00[a]
Hygroscopicity %	115.44 ± 0.21[a]	112.80 ± 0.43[b]	111.46 ± 0.55[c]	103.55 ± 0.11[d]
Dry gluten %	ND	ND	ND	8.70 ± 0.20

ND– Not detected. Values are as–is and they represent mean± standard deviation of 3 replicates and different superscripts in each row is significantly different at p<0.05 level

3.1.2 Oil absorption, water absorption and hygroscopicity

Oil absorption, water absorption, hygroscopicity and solubility are inter-related physical properties of flour. Water absorption of DDCF with different particle sizes and wheat flour were significantly different ($p < 0.05$). Further, wheat flour showed significantly lower water absorption (9.00 ± 0.00 g/g) compared to different particle sizes of DDCF. Results further indicated that water absorption of DDCF was inversely proportional to the particle size showing finer particles (< 150 µm) with higher water absorption (11.73 ± 0.23 g/g). Oil absorption of DDCF with different particle sizes and wheat flour were significantly different ($p < 0.05$). In contrast to the water absorption, oil absorption of DDCF did not vary with the particle size and it was 1.03 ± 0.23 -1.07 ± 0.12 ml/g and wheat flour showed higher oil absorption of 1.40 ± 0.00 ml/g compared to DDCF.

Hygroscopicity of the DDCF different particle sizes and wheat flour were significantly different. In addition to that and also hygroscopicity of wheat flour was significantly lower than those of DDCF of different particle sizes. In addition, there was an inverse relationship for the hygroscopicity of different particle sizes.

3.2 Dough mixing properties

Results of dough mixing properties of the flour combinations are given in Fig. 1. Water absorption of the doughs made from 100% wheat flour and DDCF incorporated flour of 5%, 20% and 25% DDCF were significantly lesser than those of 10% and 15% DDCF ($p < 0.05$) ranging from 60 to 63.2 ml/100 g. Dough development time of wheat flour and 5% DDCF incorporated flour were not significantly different ($p > 0.05$). However, it increased to 7.2–9.2 min significantly ($p < 0.05$) when the DDCF incorporation level increased. Arrival time was 2.2 min for 5% DDCF incorporated dough and it is significantly lower than arrival time of 100% wheat flour dough, and the arrival time further increased significantly with the incorporation level of DDCF increased ($p < 0.05$). Further, 5% DDCF incorporation showed a significantly lower arrival time compared to the other samples. Departure times of the samples were significantly different ($p < 0.05$) and they did not show clear relationship with the incorporation level of DDCF and it varied 12.5–17.5 min. The significantly lowest and highest departure times were shown by 5% DDCF and 20% DDCF incorporated samples respectively.

Stability time changed significantly from 11.5 min to 13.3 min, with significantly lowest values for 5% and 15% DDCF incorporated samples followed by 100% wheat flour, 10% DDCF, 25% DDCF and 20% DDCF incorporated samples. Mixing tolerance was increased significantly with the addition of DDCF from 7 BU in 100% wheat flour and 20BU in 25% DDCF substituted flour. However, incorporation of 15–25% DDCF did not show significant effect on mixing tolerance.

3.3 Properties of bread dough and finished bread

According to the Table 2, dough properties such as water requirement, mixing time, dough weight, dough temperature and proofing time significantly differed with incorporation of DDCF ($p > 0.05$). Likewise, incorporation of DDCF also affected the quality and weight of the final sandwich bread. Water requirement for making the dough using wheat and DDCF increased significantly from 59 ml/100 g to 79.75 ml/100 g.

Mixing time also increased parallel to the amount of water and DDCF added. Mixing times for 100% wheat flour was the lowest. Weight of the dough increased due to addition of more water and proofing time also increased significantly with the level of substitution of DDCF especially with 15%, 20% and 25% of DDCF incorporation while 5% and 10% incorporation of DDCF recorded significantly lower proofing times. Parallel to the increase of weight of dough, final weight also increased. The physical appearance of the breads reduced with incorporation of DDCF. The physical appearance of sandwich bread made with 5%, 10% DDCF were significantly similar to the sandwich bread made from 100% wheat flour ($p > 0.05$) and 20% and 25% incorporation did not produce satisfactory volume required for sandwich bread while 15% incorporated sandwich bread was also in acceptable quality..

3.4 Textural properties of the defatted dehydrated coconut flour incorporated sandwich bread

Textural properties of the sandwich bread made with DDCF and wheat composite flour are shown in Table 3. Fracturability of sandwich bread increased significantly with the incorporation level of DDCF ($p < 0.05$) except for the 5% DDCF incorporation level which showed significantly lower value compared to the sandwich bread of 100% wheat flour. Hardness is proportional to the fracturability and therefore, changing pattern of the hardness of sandwich bread were similar to those of fracturability. Hardness of the sandwich bread increased significantly with incorporation level of DDCF while the 25% DDCF incorporated sandwich bread had 12 fold hardness compared to the that of 100% wheat flour. Further, 100% wheat flour and 5% DDCF incorporated sandwich breads did not show variation of cohesiveness while higher replacement of wheat flour from DDCF showed lower cohesiveness. Springiness of the sandwich bread with 5% and 25% DDCF were significantly lower ($p < 0.05$) compared to the sandwich bread of other treatments including 100% wheat flour sandwich bread. Gumminess increased significantly $p < 0.05$with the incorporation of 15%, 20% and 25% DDCF. Chewiness of sandwich bread changed parallel to the gumminess. Interestingly, 5% incorporation of the DDCF showed significantly lower textural properties of the sandwich bread except cohesiveness.

3.5 Chromomeric parameters of defatted dehydrated coconut flour incorporated sandwich bread

Chromomeric parameters of sandwich bread of 100% wheat flour and different substitution levels of DDCF is shown in Table 4.

Colour was expressed as lightness (L*), redness (a*) and yellowness (b*). Lightness of the crust was significantly different among the sandwich bread of different treatments ($p < 0.05$). Sandwich bread prepared with 25% wheat flour showed highest lightness followed by those with 100% wheat flour, 10%, 5%, 20%, and 15% DDCF. Redness of the crust did not show significance difference among the treatments except for 25% DDCF incorporation level. Yellowness of crust of the sandwich bread made with 100% wheat, 5% and, 10% DDCF incorporated sandwich bread were not changed significantly and the values were higher than the yellowness of 15%, 20% and 25% DDCF incorporated sandwich breads which show similar yellowness. Crumbs of the sandwich bread of different treatments showed similar lightness and yellowness. However, redness was significantly different among the treatments ($p < 0.05$) while, crumbs of the sandwich bread made with 100% wheat flour, 5% and 10% DDCF incorporated sandwich bread showed similar redness and while 15%, 20% and 25% incorporated sandwich bread showed deeper redness compared to the other treatments.

3.6 Proximate composition of bread

Proximate composition of sandwich bread of 100% wheat flour and 5–25% DDCF incorporated flour is shown in Fig. 2. Moisture content of sandwich bread increased significantly ($p < 0.05$) with the addition of DDCF to wheat flour and it varied from 41.68% to 50.36% with incorporation of DDCF to wheat flour. Notably, moisture content of sandwich bread 5% DDCF did not have a significant difference compared to moisture content of sandwich bread of 100% wheat flour.

Ash content of the sandwich bread increased significantly with the addition of DDCF into wheat flour and, mineral content of sandwich bread with 10- 25% DDCF had highest ash content. Table 1, showed that ash content of DDCF (6.15 ± 0.02%—6.38 ± 0.02%) is much higher than that of wheat flour (0.64 ± 0.04%) and therefore, ash content of the sandwich bread increased with incorporation level of level of DDCF is justified..

Sandwich bread with 100% wheat flour had significantly lower protein content (7.39 ± 0.05%) compared to the that of 5% DDCF incorporated sandwich bread (7.50 ± 0.02%). The protein content DDCF is 1.8 times higher than the protein content of wheat flour (Table 1). Therefore 5% replacement was able to keep the protein content in a higher level. However, incorporation level of DDCF increased, protein content of the bread significantly decreased ($p < 0.05$) from 7.5 ± 0.02% to 5.01 ± 0.04%. The gluten protein is reduced due to addition of DDCF and it is good for those who look for bread with less gluten content.

Crude fibre content of the bread increased significantly proportionally to amount of DDCF of the sandwich bread. Wheat flour incorporated sandwich bread contained 2.32 ± 0.02% crude fibre while 25% DDCF incorporated sandwich bread contained 5.68 ± 0.04% crude fibre. Results showed DDCF had contributed to incorporate more crude fibre to the bread. Carbohydrates content of sandwich bread decreased significantly from 47.2 ± 0.37% in 100% wheat flour bread to 32.86 ± 0.19 in 25% DDCF incorporated bread.

4 Discussion

The comparison of the proximate composition of wheat flour and defatted dehydrated coconut flour reveals significant differences that highlight unique nutritional profiles and potential applications in various foods. Low-wheat breads, made from ingredients such as rice, corn, amaranth and buckwheat and various legumes, are emerging as viable substitutes [21, 22], appealing to health-conscious consumers and those with specific dietary restrictions. Defatted dehydrated coconut flour has potential to substitute for wheat flour based leavened and non-leavened food products as indicated by the physical and chemical properties of the coconut flour and wheat flour. Although the DDCF and wheat flour show dissimilarities in their physical and chemical characteristics as shown in Table 1, incorporation of DDCF to wheat flour to make breads and other flour based food products is possible [1, 2, 5, 13, 23].

4.1 Oil absorption, water absorption and hygroscopicity

Oil absorption, water absorption and hygroscopicity are inter-related physical properties of flour. Water absorption and hygroscopicity are related to the ability of flour to absorb water and swell giving favourable consistency to the food. Previous research reported that particle size distribution, carbohydrate content, amount of damage starch, amylose to amylopectin ratio of starch, and intra and inter molecular forces contribute to the oil absorption, water absorption and hygroscopicity of flour [4]. Particle size distribution and carbohydrate content of banana, breadfruit and wheat flour contributed the water absorption, oil absorption and hygroscopicity of those flours [4]. DDCF showed lower water absorption and it may be due to the non-starch polysaccharides in DDCF. Previously reported water absorption capacities for wheat flour were 140.00 ± 12.25% [24] and 2.07 ± 0.01 g/g [18]. Water absorption of wheat flour of 0.89 ± 0.04 ml/g was increased to 3.97 ± 0.37 ml/g when 10–50% coconut flour was incorporated to wheat flour [25]. while present study observed 9.0 ± 0.0 ml/g of water absorption for wheat flour.This may be due to the method used for determination of water absorption. According to [23] water absorption of coconut flour was 76 ± 0.1% which is lower than the 10.07 ± 0.23

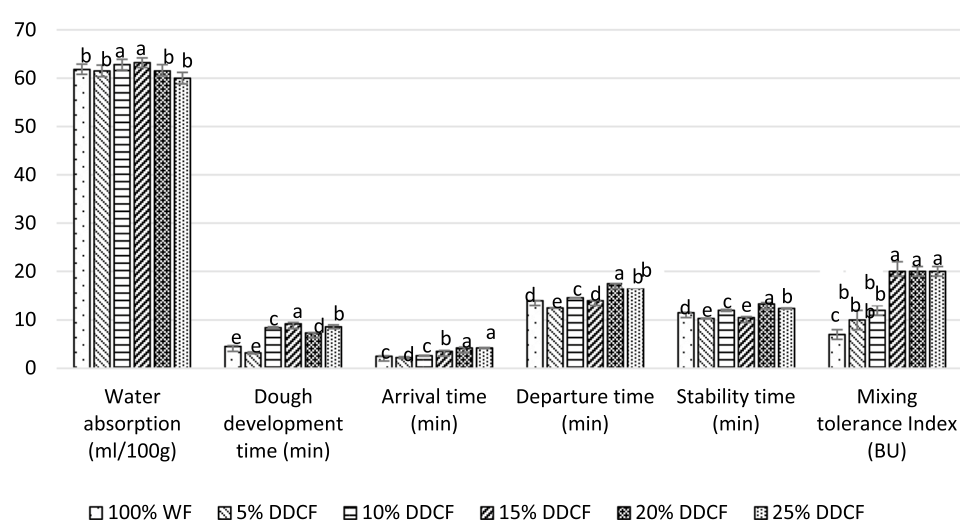

Fig. 1 Mixing properties of the dough combinations of wheat flour and defatted dehydrated desiccated coconut flour

Table 2 Dough preparation parameters and quality of finished bread of different treatments

Treatment	Dough properties					Sandwich bread properties	
	Water requirement (ml/100 g)	Mixing time (min)	Dough weight (g)	Dough temp °C	Raising time (min)	Weight (g)	Height x Length x width (cm^3)
T0	59.0 ± 1.0^{e}	18.00 ± 0.00^{f}	636 ± 1.0^{f}	34.1 ± 0.1^{c}	85 ± 1^{d}	450 ± 1^{d}	10.3 × 19.3x10^{a}
T1	60.5 ± 1.5^{e}	22.50 ± 0.00^{e}	647 ± 1.5^{e}	38.8 ± 0.2^{a}	79 ± 1^{e}	462 ± 1^{c}	10.3 × 19.3x10^{a}
T2	62.0 ± 0.5^{d}	25.50 ± 0.00^{d}	674 ± 0.5^{d}	36.6 ± 0.1^{b}	80 ± 1^{e}	469 ± 2^{b}	10.2 × 19.3x10^{a}
T3	65.5 ± 1.0^{c}	27.00 ± 0.01^{c}	678 ± 1.0^{c}	38.6 ± 1.0^{a}	106 ± 2^{c}	469 ± 2^{b}	9.9 × 19.3x10^{b}
T4	71.00 ± 1.0^{b}	30.50 ± 0.01^{b}	699 ± 1.0^{b}	36.7 ± 0.1^{b}	157 ± 3^{b}	479 ± 1^{a}	6 × 19.2 × 10^{c}
T5	79.75 ± 1.5^{a}	33.50 ± 0.01^{a}	748 ± 1.5^{a}	36.3 ± 0.0^{b}	262 ± 1^{a}	479 ± 2^{a}	5 × 19.1 × 10^{d}

Values represent means of three replicates and different superscript letters are significantly different at $p<0.05$ level

-11.73 ± 0.23 ml/g. This may be due to the method of preparation of coconut flour. The procedure for obtaining coconut is different in [23] as it is from coconut milk extraction process it is different from the DDCF preparation procedure.

Oil absorption is responsible for flavour retention and mouth feel. Oil absorption of wheat flour is 1.40 ml/g and [24] also reported closer value of oil absorption for wheat flour. Further [24] observed lowering of oil absorption capacity by incorporating rice, green gram and potato flour into wheat flour. Oil absorption capacity is affected by high fat content of flour [24]. According to the reports of [25] oil absorption of composite flour of coconut and wheat flour increased. In addition, composite flour of DDCF and wheat can show good flavour retention due to high oil absorption and the oil content of DDCF [24] when the food products are developed from the relevant composite flour.

Hygroscopicity is a function of temperature and humidity of the storage environment. According to statement [26], all the particle sizes of DDCF and wheat flour are extremely hygroscopic materials. Hygroscopicity of DDCF decreased with particle size and those values are higher than the hygroscopicity of wheat flour. The results indicate that DDCF absorbs water readily than wheat flour and this physical behaviour of DDCF may affect on dough and bread quality.

4.2 Farinograph study: flour mixing properties

Three kind of wheat flour are identified based on the farinography analysis, such as weak flour (short development time less than 2.5 min, low stability time less than 3 min, low water absorption less than 55%), medium flour (development time ranging from 2.5–4.0 min, stability time 3–10 min, water absorption 54–60%) and strong flour (long development time 4–10 min, stability time greater than 10 min, water absorption greater that 58%) as reported by [27]. None of the samples in this study showed properties of a weak flour. In term of stability time, all the flour combinations exhibited characters of a strong wheat flour. Dough development times of all flour combinations, except 5% incorporation, were in the value range of strong wheat flour. Slightly lower stability times were reported for wheat and coconut composite flour which varied from 7.1 min to 16.1 min by [28]. In this study, stability times were 10.3–13.3 min for 5–25% DDCF incorporation. However, reports indicated that stability times increased up to 18 min for wheat and 10–20% coconut flour composite flour [29]. [29] further stated that if coconut flour was increased to 30% stability time was not detected.

Table 3 Textural properties of defatted dehydrated coconut flour incorporated sandwich bread

Treatment	Fructurability (g)	Hardness (g)	Cohesiveness	Springiness (mm)	Gumminess (mm)	Chewiness mJ
T0	455 ± 34^{e}	427 ± 30^{f}	0.72 ± 0.01^{a}	4.22 ± 0.05^{a}	329 ± 21^{e}	13.63 ± 0.75^{e}
T1	340 ± 25^{f}	320 ± 25^{e}	0.73 ± 0.01^{a}	3.95 ± 0.10^{b}	248 ± 20^{f}	9.63 ± 0.93^{f}
T2	633 ± 17^{d}	588 ± 17^{d}	0.67 ± 0.01^{b}	4.22 ± 0.05^{a}	434 ± 15^{d}	17.97 ± 0.49^{d}
T3	1960 ± 186^{c}	1753 ± 153^{c}	0.59 ± 0.01^{c}	4.19 ± 0.11^{a}	1151 ± 100^{c}	47.57 ± 2.97^{c}
T4	3331 ± 289^{b}	2950 ± 226^{b}	0.58 ± 0.02^{c}	4.19 ± 0.06^{a}	1936 ± 107^{b}	79.43 ± 3.23^{b}
T5	5852 ± 697^{a}	5217 ± 505^{a}	0.58 ± 0.07^{c}	3.75 ± 0.14^{c}	3376 ± 72^{a}	124.20 ± 7.07^{a}

values represent means of three replicates and different letters in superscripts are significantly different at $p<0.05$ level

Table 4 Chromomeric parameters of defatted dehydrated coconut flour incorporated sandwich breads

Treatment	L*		a*		b*	
	Crust	Crumb	Crust	Crumb	Crust	Crumb
T0	59.3 ± 1.1^{b}	68.5 ± 5.2^{a}	14.6 ± 1.3^{a}	0.9 ± 0.3^{b}	30.8 ± 0.8^{a}	11.4 ± 0.7^{a}
T1	50.4 ± 1.5^{c}	69.4 ± 1.5^{a}	17.4 ± 1.7^{a}	0.7 ± 0.0^{b}	28.4 ± 2.6^{a}	11.5 ± 0.8^{a}
T2	54.3 ± 3.8^{bc}	63.4 ± 1.5^{a}	16.3 ± 1.3^{a}	1.3 ± 0.3^{b}	28.9 ± 1.4^{a}	11.0 ± 1.2^{a}
T3	42.6 ± 2.4^{e}	63.5 ± 3.2^{a}	16.0 ± 0.9^{a}	1.9 ± 0.2^{a}	20.8 ± 3.6^{b}	14.0 ± 1.2^{a}
T4	48.1 ± 2.9^{d}	64.7 ± 0.9^{a}	16.8 ± 2.9^{a}	1.9 ± 0.1^{a}	20.8 ± 1.6^{b}	11.3 ± 1.7^{a}
T5	69.0 ± 3.6^{a}	68.3 ± 1.2^{a}	4.5 ± 0.1^{b}	2.1 ± 0.4^{a}	21.6 ± 2.9^{b}	13.1 ± 0.5^{a}

values represent means of 3 replicates and different superscripts letters in each column are significantly different at $p<0.05$ level

Water absorption of all flour combinations was greater than 58% and it is in the range of a strong wheat flour. Therefore, all the flour combinations represented a strong wheat flour suggesting suitability of bread preparation. According to [28], composite flour of coconut flour and wheat flour (Coconut flour 5–30% and wheat flour 95–70) showed water absorption of 55.7 -54.6%, which is slightly lower than the values of present study. Mixing behaviour of series of composite flour of coconut (0%0.10%, 20% and 30%) and wheat flour indicated similar trend of water absorption where wheat flour has 61% 30% coconut flour incorporation reported 58% [29]. Compared to arrival time reported to by [29], our DDCF and wheat combinations needs lower dough development times. [29] used same type of coconut flour similar to DDCF, but this study focused on specific particle size of 500 µm-150 µm while [29] used without particle size separation.

4.3 Properties of bread dough and finished bread

During the preparation of dough with T0-T5 flour combinations, increased levels of DDCF required more water, aligning with its water absorption capacity. However, dough mixing studies indicated that water absorption did not strongly correlate with the amount of DDCF added. The differing physicochemical properties of DDCF flour and other ingredients added required extra water for optimal dough quality. Adjustments in water and mixing time were made accordingly, similar to findings reported by [30], which noted that whole meal white purple wheat flour required 1.3 times more water than white purple wheat flour due to higher fiber content. Similar to this observation, [28] also indicated that coconut-wheat flour blends needs more water for hydration of particles and longer hydration of the flour mixture particles, the longer the formation of gluten network [28]. Table 2 shows that mixing time had to increase with higher DDCF substitution levels until proper dough consistency was obtained. The addition of DDCF contributed to increased dough weight, partly due to water content. Despite use of cool water at 11 °C dough temperature raised to 34.1 °C to 38.8 °C during rising. There was no clear relationship between dough temperature and the DDCF: wheat flour ratio. Doughs with 0%, 5%, and 10% DDCF had shorter rising times (79–85 min), while those with 15%, 20%, and 25% DDCF had longer rising

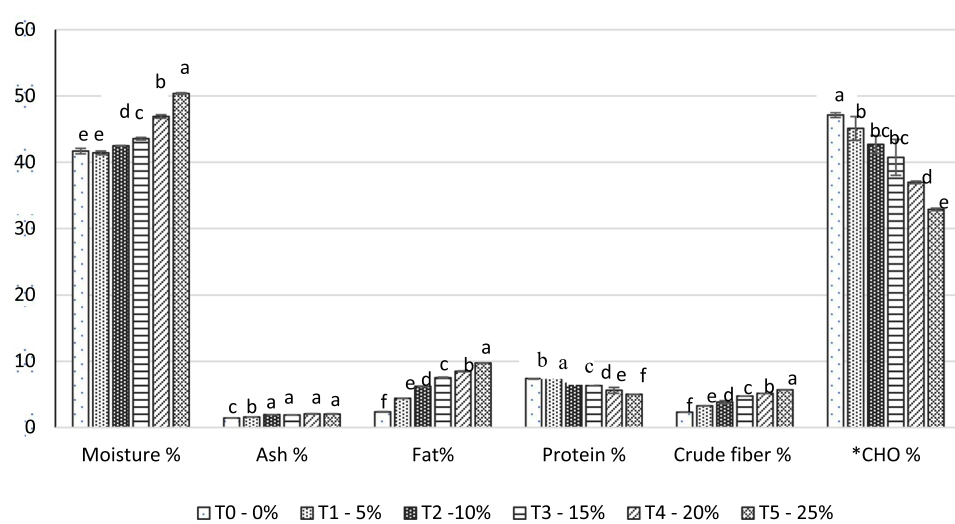

Fig. 2 Proximate composition of defatted dehydrated coconut flour incorporated sandwich breads

times (106, 152, and 262 min, respectively) and reason is due to incorporation of more DDCF and formation is gluten network delayed due to dilution of gluten protein [28, 30].

The dough of 520 g was taken for sandwich bread tray and the results show that the sandwich bread has different final weights (Table 2). Weight loss of 13.4%, 11.1%, 9.8%. 9.8%, 7.9%, 9.6% were observed for 0%, 5%, 10%, 15%, 20 and 25% incorporation of DDCF respectively. Weight loss lower when more DDCF is added.

Table 2 show that dimensions (height, width and length) of the sandwich bread is severely affected by addition of DDCF. Substitution of 5–15% DDCF has no influence on the height, width and length of the sandwich bread or the appearance of the sandwich bread. Shape and appearance of sandwich bread are major concerns of the consumers. Substitution of 20% has slightly lower height sandwich bread and appearance is also slightly affected. Regular bread made from rice and wheat flour also observed lower loaf volume with increased rice flour [31] while [29] also reported similar results for regular bread with 20% coconut flour and 80% wheat flour. Similarly, 25% of substitution of DDCF in sandwich bread formula is not successful as it has not given desirable height or appearance and therefore, it is not recommended according to the result of this experiment. Previous study also reported that bread volume of non-wheat flour incorporated bread is severely affected due to high fibre content including dietary fibre [5, 28–30].

4.4 Textural properties of the defatted dehydrated coconut flour

Fructurability is the force necessary to crumble or break the bread slice. It increased with the incorporation of DDCF to wheat flour. The change of hardness of bread was also in the same direction with fructurability. In contrast, cohesiveness of the sandwich bread was reduced significantly with incorporation of DDCF. Therefore, crump is not soft and it tended to hard and break. The decreasing trend of cohesiveness with the incorporation of DDCF also supported results of fructurability and hardness. The gluten present in wheat flour contributes to cohesiveness [28, 30]. As more DDCF is added cohesiveness is affected due to decreasing gluten content. This observation is supported [25] where pasting property of wheat and coconut composite flour was evaluated. Replacement of wheat flour from coconut flour could reduce gluten content from 8.25% in 100% wheat flour to 6.51% with 25% DDCF incorporation. Therefore gluten content is not sufficient to have proper net work for sandwich bread. Chewiness determines the energy needed to disintegrate the relevant food to the point of being swallowed therefore DDCF incorporated sandwich bread need more energy to swallow. This study used constant yeast levels throughout the experiment. However, Increasing yeast level in bread recipe help for improved bread quality such as lower hardness., improved chewiness and bread volume [30]. In addition, detrimental effect of bread with composite flour of wheat and non- wheat flour are due to the soluble and insoluble -non starch polysaccharides, cellulose and lignin [30]. As DDCF contains high concentration of soluble and insoluble polysaccharides, hemicelluloses, celluloses higher incorporation of DDCF could produce sandwich bread with lower quality.

4.5 Chromomeric parameters of the bread

Sandwich bread made in this study had lighter crumb colour and darker crusts which is desirable when bread is concerned. Rice flour incorporation to wheat flour significantly affected the colour of the bread [31]. The colour difference of crust and crumb is justified as crust is exposed to more heat. The dark brown colour of bread could be due to reactions between proteins and the carbohydrate in the dough at high temperature. It was observed that bread baked at lower temperature and shorter time has higher lightness compared with those bread baked at high temperature [31]. The sandwich bread from all the treatments of this study showed non- significant variation of lightness & yellowness of crumb. Redness of the crumb show a significant difference when the substitution level of DDCF increased. Desired colour can be obtained by improving baking time and temperature to fulfill the appearance of the bread. Previous study [31] reported that regular bread made from wheat flour had lightness, redness and yellowness combinations for crumb 85.32 ± 1.28, 1.34 ± 0.24 and 29.46 ± 0.68 respectively while those for crust were 64.11 ± 1.41, 18.14 ± 0.16 and 28.41 ± 0.15 respectively. According to [24] crust colour of regular bread changed with incorporation of 10%, 20% and 30% coconut flour compared to 100% wheat flour regular bread, however, curst colour changed significantly. In our results sandwich bread of wheat flour had lighter, lower redness and lower yellow crumb while crust lighter, higher redness, strong yellow crumb. When DDCF incorporated to wheat flour sandwich bread had darker crust and crumb compared to 100% wheat flour sandwich bread in present study.

4.6 Proximate composition

Moisture content of bread is important criteria because it relates to the firmness of the bread [32]. If the moisture content is less it accelerates the formation of cross links between starch and protein. Moisture content of Coconut flour incorporated regular bread varied between 34 and 36% [5], which was less than the our study (41.68%—50.36%). Reason may be due to type of bread. According to [5], 30% coconut flour incorporated regular bread had 26.82–33.84% moisture while wheat flour bread had 27% moisture. Moisture content differs in type of bread and sandwich bread is less firm than other bread. The sandwich bread containing DDCF was incorporated more water (Table 2) during the preparation of dough. The high soluble and insoluble carbohydrates [7] retain more water and it is not released in the baking process.

Coconut flour contains calcium (2.71–4.52 mg/100 g), iron (1.57–2.06 mg/100 g), magnesium (9.58–10.53 mg/100 g) and sodium (502–943 mg/kg) as major minerals [33] and these are included in ash content. The addition of DDCF has increased mineral content of the sandwich bread. Sandwich bread with 100% wheat flour has 1.44% ash content and it increased to 2.04% in sandwich bread with 25% DDCF. This observation is supported by [4] where ash content of 5–50% coconut flour incorporated bread reported 1.72–4.70% ash content while replacing wheat flour with chestnut flour of 5–50%, ash content increased to 1.56–2.68%.

According to the Fig. 2, fat content of sandwich bread increased proportionally to the DDCF. Similar observation was reported by [4, 34] when coconut flour incorporated to wheat flour in 5–50%. Proximate composition of DDCF showed that it contained 9.58 ± 0.31% -9.81 ± 0.04% fat and wheat flour contained 1.18 ± 0.15% fat. Further, as a result of replacement of wheat flour from DDCF, fat content of sandwich bread is increased. Fat content of sandwich bread with 100% wheat flour is the lowest of all (2.37 ± 0.05%) while it increased to 9.72 ± 0.04% when the substitution level of DDCF increased from 5 to 25%. Physico-chemical properties of flour decide the structure of the food product made from them [35]. Therefore, incorporation of DDCF is good option to increase fibre content of the bread and to increase the daily fibre intake. Wheat contains starchy polysaccharides and it imparts desirable effects in bread making. Good flavour, taste and appearance of bread are due to the starch content. However, coconut has non-starchy polysaccharides and therefore DDCF is healthier compared to wheat flour and therefore, it is possible to reduce starch polysaccharide in meals in wheat flour is substituted with DDCF. Desirable qualities such as proofing, fracture stress of bread crumb, loaf volume, bread yield, taste, appearance and shelf life of bread made from wheat flour due to starch and gluten is reported [31]. As DDCF does not have enough starch and gluten, the incorporation should be done by keeping the desirable qualities of the bread.

5 Conclusion

Defatted desiccated coconut flour has potential to substitute for wheat flour for sandwich bread up to 5–15% for a sandwich bread with good volume. However, 5–10% is more favourable when the bread volume and weight, textural properties are concerned. Textural properties indicated that 5–10% incorporation produced sandwich bread which is similar to sandwich made with wheat flour. By replacing 5–10% wheat flour, increased fibre content and reduced gluten protein in the bread was achieved. More studies needed to improve the formulation to incorporate higher incorporation of DDCF for an acceptable quality of sandwich bread.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate National guidelines were followed during collecting coconut for current study.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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