Journal of Food Bioactives
International Society for Nutraceuticals and Functional Foods
Original Research
J. Food Bioact. 2022;19:164–170

Doum fruit (*Hyphaene thebaica* (L.) Mart.) supplementation improves glycemic index of wheat flour bread in apparent healthy volunteers

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DOI: 10.31665/JFB.2022.18322
Received: August 30, 2022; **Revised received & accepted:** September 28, 2022
Abbreviations: AUC, Area Under Curve; AT, Ambient Temperature; GI, Glycemic Index; PA, Proofing Ability; RT, Refrigerated Temperature; SV, Specific Volume
Citation: Aminu, K., Mohammed, A., and Ameh, D.A. (2022). Doum fruit (*Hyphaene thebaica* (L.) Mart.) supplementation improves glycemic index of wheat flour bread in apparent healthy volunteers. J. Food Bioact. 19: 164–170.

Abstract

The increasing demand for plant-based enriched diet has encouraged the food industry to produce fiber-supplemented products such as composite breads using locally available plants products. In the present study, composite breads from doum (*Hyphaene thebaica* Mart.) fruit and wheat flours were produced. Control bread (0% doum fruit) and four different composite breads (10%, 20%, 30% and 40% doum fruit) were produced. The physical properties, sensory evaluation, shelf-life, proximate composition, antinutrients content and glycemic index (GI) of the composite breads were investigated. Supplementation of wheat bread with doum fruit improved the nutritional content by increasing the fiber and mineral contents with reduction in phytate content. The composite bread, especially at 40% doum fruit inclusion was moderately accepted by the product testing panels. Inclusion of doum fruit further improved the shelf-life of the composite breads at both ambient and refrigerated temperatures. Similarly, the GI was observed to improve with doum fruit inclusion at all the concentration used. Conclusively, inclusion of doum fruit to the wheat flour produced composite breads with improved physical and nutrients quality with moderate overall acceptability and lower GI.

Keywords: Composite bread; Doum fruit; Glycemic index; Sensory evaluation; Wheat bread.

1. Introduction

Glycemic index (GI) as an indicator of glycemic response categorizes food based on the postprandial blood glucose response compared with a reference food. One of the major dietary changes in the modern world has been the increased consumption of fiber-depleted foods with high GI which coincides with rising rates of metabolic disorders like diabetes (Pontifex et al. 2021). Foods with low GI are rich in dietary fibers and regulate glycemia, contribute mostly to increase satiety and food intake (Zafar et al. 2019). Globally, wheat flour is regarded as a common ingredient in bread making and a good source of energy-rich diet, mostly characterized as having high GI food (≥70%) (Borczak et al. 2018). In this regard, studies have shown that wheat bread can be enriched and fortified by some plants that are abundant in functional nutrients which may assist in boosting its beneficial health effect and lower the GI (Binou et al. 2022; Onipe et al. 2015). Plant parts such as fruits and vegetables can be used to fortify wheat bread and could enhance the metabolism of carbohydrates in the system, with overall beneficial effects for people with diabetes and other related disorders (Seal et al. 2021).

Doum (*Hyphaene thebaica* Mart.), family Arecaceae, is an edible fruit round in shape usually grown in a western and northern part of Africa (Khalil et al. 2020). Doum fruit is a good source of nutrients essential for improving the well-being of humans and animals. The edible part of the doum fruit is consumed fresh or dried, and has been a popular component of tea preparation consumed for refreshment, regulation of body weight and blood glucose (Shady et al. 2021). Studies have reported that doum fruit possessed antioxidant (Hsu et al. 2006), antimicrobial (Hussein et al. 2011), antihyperlipidemic and blood glucose lowering ability (Shady et al. 2021). Due to these properties, doum fruit could be desirable for plant-based food fortification and hence, the basis of the present study. In line with this, Aboshora et al. (2016) reported that wheat bread supplemented with doum fruit improved the nutritional content and antioxidant activity of the bread and was acceptable by the consumers. However, effect of such composite bread on the glucose response and GI is still speculative. Hence, the study is aimed to investigate the physical properties, sensory evaluation, proximate composition, antinutrients content, glucose response and GI of composite bread produced from doum fruit and wheat flour.

2. Materials and methods

2.1. Sample collections and preparation

Wheat flour was purchased from the Kasuwan Bacci market, Kaduna. The doum fruits were collected fresh from Kaduna and identified at the herbarium, Department of Botany, Ahmadu Bello University, Zaria with a voucher number of ABU03391. The edible outer cover was carefully removed and shade dried for two weeks and was later milled in hammermill into fine flour.

2.2. Bread making from wheat and doum flour

The control used contained 0% of doum fruit whereas other four (4) different composites breads were produced by inclusion of the fruit at 10% (B1), 20% (B2), 30% (B3) and 40% (B4). Briefly, the wheat flour and the various proportions of the doum fruit were mixed in the mixer bowl for 1 minute. Afterwards, 5% butter, 3% sugar, 1% salt, 1.5% compressed yeast, previously dissolved in water, were added followed by the addition of water consistently. Dough kneading process was continued and the kneaded dough was placed in baking pans and proofed at room temperature. After an hour of fermentation, the dough was punched down to remove gases, it was then proofed for further 1 hour and was baked at 205 °C for 30 minutes.

2.3. Determination of physical properties of the composite breads

The physical properties of the breads [height (H), breadth (B), weight (W), length (L), proofing ability (PA) and specific volume (SV)] were determined according to the method by Oladunmoye et al. (2010). The H, B and L were determined using a meter rule at the nearest 0.1 cm while the weight was determined using a weighing balance. The PA was measured through subtracting the initial height of the dough before proofing it from the final height after proofing and the values were multiplied by 100%.

$$\text{Specific volume}\left(\frac{\text{cm}^3}{\text{g}}\right) = (\text{L} \times \text{B} \times \text{H})/\text{W}$$

2.4. Determination of proximate composition of the composite breads

The proximate compositions (moisture, ash, total protein, fat and fiber contents) of the composite breads were conducted using the AOAC (2006) method. The carbohydrate content was determined by difference and all determinations were carried out in triplicates.

2.5. Determination of antinutrient contents of the composite breads

The method reported by AOAC (2006) was again employed for the determination of the antinutrient contents (tannin, oxalate, phytate and saponin).

2.6. Sensory evaluation

Consumer-oriented testing was used by the modified methods of Gacula and Kubala (1975), and Watts *et al.,* (1989). Samples were coded as C, B1, B2, B3 and B4 for doum fruit inclusion at 0%, 10%, 20%, 30% and 40% respectively. The sensory analysis was conducted on the breads 12 hours after baking. The consumer-oriented testing consisted of 30 untrained randomly selected people (15 females and 15 males) that were able to read questionnaires. They were required to differentiate between taste, appearance, odor and texture of the bread samples. Before serving, the samples were warmed at 50°C to enhance the flavor and odor detection. The quality of the coded samples related to the control was rated on a sensory evaluation sheet using a 7-point hedonic scale for the taste, appearance, odor and texture.

2.7. Assessment of the shelf life of the composite bread

The control bread (0% doum fruit) and the composite breads produced were packed in a polypropylene bag for the shelf-life study and was then kept at room temperature and refrigerator for seven (7) days. The visual spoilage at both Ambient Temperature (AT) and Refrigerated Temperature (RT) was recorded accordingly (Kaur and Kaur, 2013).

2.8. Human subjects

A total of fifty (50) apparently healthy subjects from Ahmadu Bello University, Zaria, Nigeria, aged 18–50 years, participated in this study. The subjects have average fasting blood glucose level of 5.45 ± 0.22 mM. The ethical clearance permissions for this study were obtained from Institutional Ethical Committees of Ahmadu Bello University, Zaria (ABUCUHSR/2022/003) and Ministry of Health, Kaduna State (NHREC/17/03/2018). Informed written and/or verbal consent was sought from each subject before inclusion into the study.

2.9. Determination of glycemic response and glycemic index.

Glycemic responses were determined using FAO/WHO (1998) method. Fifty (50) volunteers were recruited and grouped in to five (5) groups with 10 volunteers (5 females and 5 males) randomly included into each group. These volunteers were requested to undergo an overnight fasting of 10–12 hours. The fasting blood

Table 1. : Physical properties of the composite breads

Parameters	Length (cm)	Breadth (cm)	Height (cm)	Weight (g)	PA (%)	SV (cm^3/g)
Control	25.50±0.50^a	9.93±0.12^a	7.67±0.23^c	717.67±4.04^a	83.00±5.77^c	2.70±0.06^c
B1	26.10±0.26^a	9.70±0.17^a	7.43±0.21^c	761.00±4.00^b	80.00±0.01^c	2.47±0.07^c
B2	26.47±0.25^a	9.50±0.16^a	5.47±0. 06^b	768.00±3.00^b	66.67±5.77^b	1.79±0.01^b
B3	26.30±0.17^a	9.80±0.20^a	5. 03±0.12^b	809.67±6.11^c	56.67±4.71^{a,b}	1.66±0.03^b
B4	26.50±0.01^a	10.01±0.11^a	4. 03±0.15^a	822.67±3.21^d	40.00±10.00^a	1.31±0.06^a

Values were expressed as mean ± SD (n = 3). Values with different letters in a column are significantly different ($p < 0.05$). Control = 100% wheat flour breads, B1 = 10% DFF breads, B2 = 20% DFF breads, B3 = 30% DFF breads and B4 = 40% DFF breads. DFF = Doum Fruit Flour; PA = Proofing Ability; SV = Specific Volume.

samples were collected by pricking the fingertip and the fasting blood glucose level was assessed using Accu-Chek glucometer, Roche, Germany. Pure glucose solution was used as the standard against the wheat bread and other composite breads. The blood samples were taken at 0, 30, 60, 90 and 120 minutes. A blood glucose response chart was plotted from the average blood glucose concentrations obtained before and after-meal ingestion as a function of time.

The glycemic index (GI) of each subject was calculated using the Wolever et al., (1985) method as follows:

$$GI = \frac{\text{Mean Incremental Area Under blood-glucose Curve (AUC) for composite bread}}{\text{Mean Incremental Area Under blood-glucose Curve for wheat bread only}} \times 100$$

The glycemic index was categorized as low (0–55%), moderate (56–69%), and high (≥70%).

2.10. *Data analysis*

Data collected was analyzed using Statistical Package for Social Sciences (SPSS) IBM software version 21. All data obtained was expressed as mean ± standard deviation. The data was analyzed using analysis of variance (ANOVA). Tukey *post hoc* test was carried out where necessary. Significant difference was established at $p < 0.05$.

3. Results and discussion

3.1. *Physical properties of the composite breads*

The results of the physical properties (length, height, weight, breadth, proofing ability and specific volume) of the composite breads are presented in Table 1. Temperature and time of baking were not determining factors for the physical qualities of the composite breads as all the breads were processed at the same temperature and time. The results indicated that inclusion of doum fruit significant ($p < 0.05$) decreased the height, proofing ability and specific volume of the composite breads compared to wheat bread, used as a control (Table 1). However, the decrease in the height and specific volume of composite bread at 10% doum fruit inclusion was not significantly ($p > 0.05$) different from the wheat bread. The decrease in specific volume and proofing ability with increasing amount of doum fruit were in line with a previous study (Aboshora et al. 2016). The data further revealed that there was a significant increase ($p < 0.05$) in the weight of the composite breads as the amount of doum fruit increase compared to the wheat bread (Table 1). Increase in weight has great economic benefit on bread at the retail end as consumers believe that such breads have more substance in relation to other for the same price. Studies have reported that the increase in weight and decrease in height, proofing ability and specific volume of the composite breads could be attributed to an increase fiber content (Pathak et al. 2017; Obiegbuna et al. 2013). High fiber content dilutes the gluten content of the wheat flour and impedes with the optimal gluten matrix formation during fermentation (Ma et al. 2021). Moreover, inclusion of doum fruit did not significantly ($p > 0.05$) affect the length and breadth of the composite breads.

3.2. *Proximate compositions of the composite bread samples*

The proximate compositions of the composite breads are presented in Table 2. The results revealed that the moisture, ash, total lipid and fiber contents were significantly ($p < 0.05$) increased with the inclusion of doum fruit compared to that of wheat flour. This further support the data on weight and specific volume in relation to the higher fiber content of the composite breads. Besides, high fiber content is beneficial in regulation of hyperlipidemia, appetite, hyperglycemia and chronic inflammation (Barber et al. 2020).

Table 2. : Proximate composition of the composite breads

Breads	Moisture(%)	Ash(%)	Lipid(%)	Protein(%)	Fibre(%)	Carbohydrate(%)
Control	25.47±1.12^a	1.35±0.39^a	13.83±1.58^a	8.17±1.01^c	0.00±0.00^a	51.19±2.25^d
B1	30.57±1.92^b	2.78±0.42^b	12.57±1.28^a	6.42±0.82^b	0.53±0.08^b	47.67±0.60^d
B2	37.57±0.83^d	1.22±0.38^a	16.10±1.23^b	5.20±0.02^a	0.90±0.05^b	39.87±0.78^c
B3	34.03±0.71b^c	1.90±0.72^{a,b}	21.03±0.78^c	5.25±0.01^a	2.67±0.13^c	37.78±0.68^{b,c}
B4	32.80±0.17^b	2.12±0.15^{a,b}	24.33±1.00^c	5.83±1.88^a	3.27±0.06^d	34.92±0.75^a

Values were expressed as mean ± SD (n = 3). Values with different letters in a column are significantly different ($p < 0.05$). Control = 100% wheat flour breads, B1 = 10% DFF breads, B2 = 20% DFF breads, B3 = 30% DFF breads and B4 = 40% DFF breads.

Table 3. : Antinutrient contents of the composite breads (mg/100g)

Breads	Tannin	Oxalate	Phytate	Saponin
Control	1.20±0.70[a]	0.04±0.01[a]	0.16±0.02[b]	30.75±0.01[a]
B1	3.60±0.09[c]	0.08±0.03[a]	0.11±0.01[b]	39.20±0.91[b]
B2	2.20±0.07[b]	0.13±0.01[b]	0.06±0.02[a]	52.40±1.92[c]
B3	2.55±0.14[b]	0.11±0.01[b]	0.06±0.01[a]	51.65±1.28[c]
B4	2.65±0.06[b]	0.12±0.02[b]	0.04±0.01[a]	52.15±3.15[c]

All results are in mg/100g. Values were expressed as mean ± SD (n = 3). Values with different letters in a column are significantly different ($p < 0.05$). Control = 100% wheat flour breads, B1 = 10% DFF breads, B2 = 20% DFF breads, B3 = 30% DFF breads and B4 = 40% DFF breads.

The disparity in the moisture content of the composite breads was consistent with varied water quantity used in the substitution of the different doum fruit ratios. Similarly, the increase in moisture correlates well with the increase in the fiber content. The ash content is basically the inorganic minerals necessary for supporting various biological and nutritional processes in the system. In multiple studies, doum fruit was reported to content high amount of inorganic minerals such as calcium, phosphorus, sodium and potassium (El-Hadidy and El-Dreny, 2020; Aboshora et al. 2016; Hussein et al. 2010), and hence, doum fruit could supplement the mineral content of the wheat bread as evidence by the high ash content (Table 2). The results further revealed that there was significant ($p < 0.05$) reduction in protein and carbohydrate contents of the composite compared to that of the wheat bread (Table 2), which is in line with previous study by Hussein et al. (2010).

3.3. Antinutrient contents of the composite breads

The antinutrient contents (tannin, oxalate, phytate and saponin) of the composite breads were presented in Table 3. Data revealed that, the tannin, oxalate and saponin contents of the composite breads significantly ($p < 0.05$) increase with doum fruit inclusion although not dependent on the amount of the doum fruit compared to that of the wheat bread. However, the phytate content significantly ($p < 0.05$) decreased with doum fruit inclusion compared to the wheat bread (Table 3), and was in agreement with previous studies (Ayele et al. 2017; Mashayekh et al. 2008). It has been reported that phytate interferes with starch hydrolysis and chelates important minerals crucial for normal physiological functions by reducing their bioavailability (Kumar et al. 2020). Thus, the reduction in phytate content as the amount of doum fruit increases could make the minerals readily available for absorption and subsequent functions in the system.

3.4. Sensory evaluation and shelf-life of the composite breads

The results of the sensory evaluation using consumer-oriented testing protocol is shown in Figure 1. The taste, appearance, odour and overall acceptability of all composite breads did not differ significant ($p > 0.05$) compared to those of wheat bread. However, there was a decrease in the texture of the composite breads as the amount of doum fruit increase, which was found significant ($p < 0.05$) for composite breads supplemented with 30% and 40% doum fruit (Figure 1). This implies that the composite breads at 30% and 40%

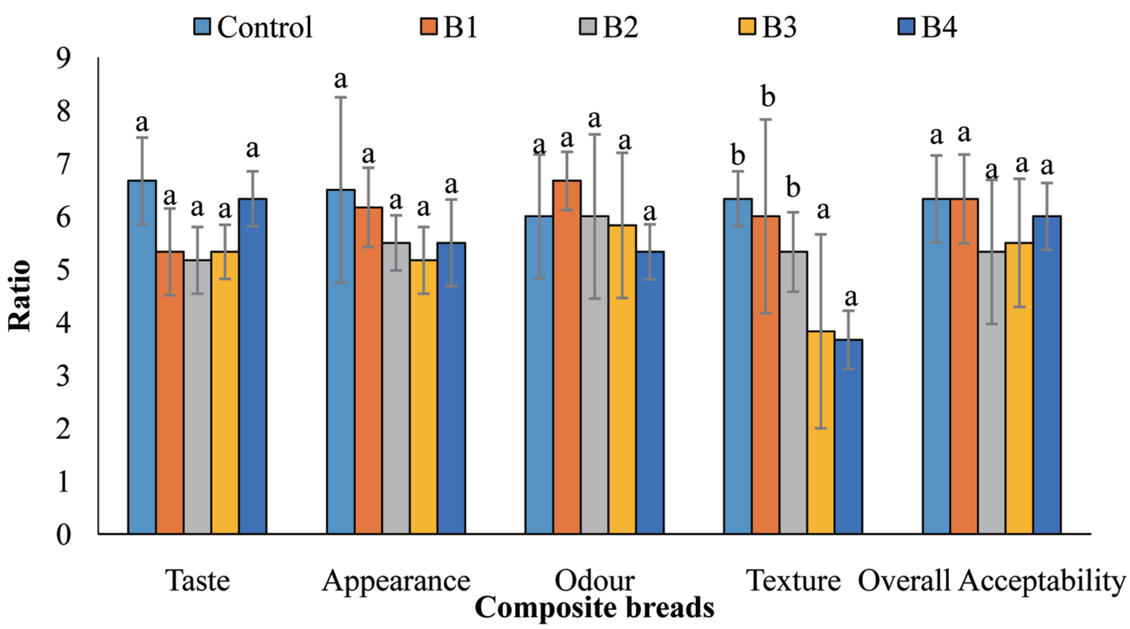

Figure 1. Consumer oriented testing of the composite breads. B1, B2, B3 and B4 are the various composite breads with 10%, 20%, 30% and 40% doum fruit supplementation. Values with different superscript in the chart are significantly different ($p < 0.05$).

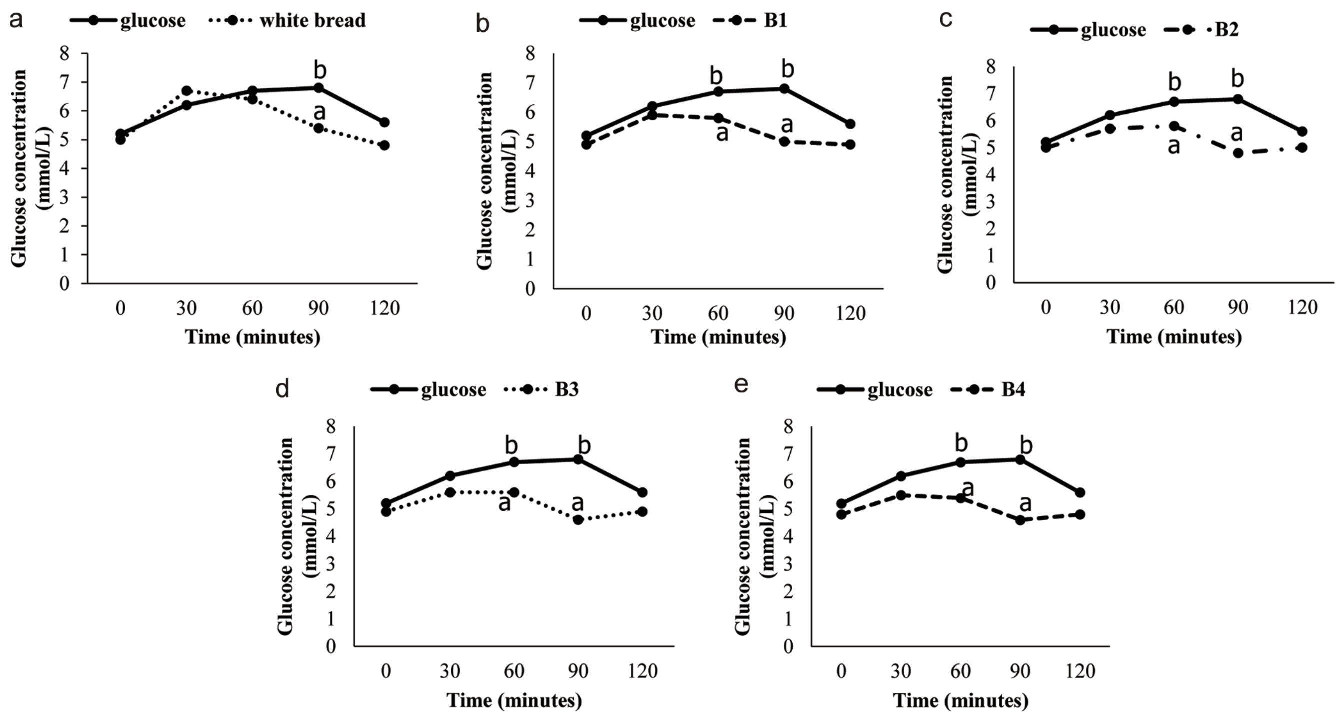

Figure 2. Glucose response curve for the wheat flour bread (a), 10% doum fruit (b), 20% doum fruit (c), 30% doum fruit (d) and 40% doum fruit (E) breads, using glucose as the control. B1, B2, B3 and B4 are the various composite breads with 10%, 20%, 30% and 40% doum fruit supplementation. Values with different superscript in each chart are significantly different ($p < 0.05$).

became comparatively harder than the wheat bread, attributed to increase moisture retention. Overall, based on present data, (taste, appearance, odour and overall acceptability) inclusion of doum fruit resulted in development of breads with satisfactory properties and overall acceptability.

In order to observe the shelf-life of the composite breads, samples were stored at an ambient temperature (AT) while others were kept at refrigerated temperature (RT). For the wheat bread samples, molds growth appeared on the fourth- and fifth- day at AT and RT respectively. Similarly, molds growth appeared at fifth and sixth day for the composite breads with 10% and 20% doum fruit at AT respectively. It was further observed that spoilage at RT usually began after 24 hours in relation to AT. It was again interesting that inclusion of doum fruit further delayed the spoilage with no molds after seventh day for breads with 30% and 40% doum fruit inclusion at both temperatures. Ordinarily, molds growth and food spoilage tend to reduce at refrigerated temperature (Rawat, 2015). The beneficial effect of the doum fruit to improve the shelf-life and delay spoilage of the composite breads could be attributed to some key metabolites such as coumarins, catechins, vanillin and ferulic acid present in doum fruit that were reported to possessed antimicrobial activity (Nicolau-Lapeña et al. 2021; Ma et al. 2019; Widelski et al. 2018).

3.5. Glycemic index of the composite bread samples

The postprandial blood glucose responses and glycemic index of the composite breads are presented in Figure 2 and Table 4, respectively. Pure glucose solution was used as the control in this analysis. From the results, inclusion of doum fruit at various amount (10%, 20%, 30% and 40%) improved the postprandial hyperglycemia compared to the control group, and was significant ($p < 0.05$) at 60 and 90 minutes (Figure 2). For the wheat bread, the reduction in postprandial hyperglycemia was only significant at 90 minutes compared to control group. All subjects showed normal glycemic responses to the composite bread via improving glycemia. On the other hand, inclusion of doum fruit significantly ($p < 0.05$) improved the GI of the composite breads (Table 4). The GI decreased as the amount of the doum fruit increased, with bread produced with 40% doum fruit (B4) showed significantly ($p < 0.05$) the least GI compared to wheat bread as well as other test groups (B1, B2 and B3). Moreover, all the composite breads showed moderate glycemic index (0–55%), based on Wolever et al. (1985). The data of the present study further revealed positive correlation of improving glycemia and increasing GI to an increase fiber content of the composite breads and was in line with previous studies (Fratelli et al. 2018; Burton et al. 2011). Interestingly, the GI of the bread at 40% doum fruit inclusion was significantly ($p < 0.05$) lower compared to the wheat bread and other composite breads (Table 4),

Table 4. : Glycemic index of the composite breads

Breads	Glycemic index (%)
Wheat bread	65.71 ± 14.24^{c}
B1	44.97 ± 9.24^{b}
B2	43.84 ± 14.43^{b}
B3	42.52 ± 8.55^{b}
B4	22.53 ± 3.69^{a}

Values with different superscript in a column are significantly different ($p < 0.05$). B1 = 10% DFF breads, B2 = 20% DFF breads, B3 = 30% DFF breads and B4 = 40% DFF breads, DFF = Doum Fruit Flour, GI = Glycemic Index.

which could be attributed again to higher fiber content. In line with this, studies have shown that the amount and type of dietary fiber affect the GI of foods (Vlachos et al. 2020; Hodge et al. 2004). It is also recommended that the GI of the composite breads could be improved by eating the breads with other supplement such as vegetables, sardines to mention but few.

4. Conclusion

Based on the results of the present study, it is concluded that the inclusion of doum fruit to the wheat flour produced composite breads with improved physical and nutrients quality with moderate overall acceptability. Additionally, the composite breads improved the glycemia and have low GI. It is therefore, recommended for further investigation on the diabetic patients to verify the beneficial role of the composite breads on glycemia in diabetes condition.

Acknowledgments

None to declare.

Funding

No external funding was received for this work.

Conflict of interest

The authors wish to confirm that there is no known conflict of interests associated with this publication and there has been no financial support for this work that could have influenced its outcome.

Author contributions

KA: Conduct laboratory work and did formal analysis of the results, AM and DAA: Supervised the laboratory work and the analysis of the results. KA: Drafted the manuscripts. AM and DAA: Corrections and observations. The author(s) read and approved the final manuscript.

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