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Research Article

Nutritional And Anti-Diabetic Properties of Cookies Supplemented with Processed Vitex Doniana Leaf

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Abstract

This study investigated the potential of supplementing wheat flour with processed *Vitex doniana* leaf flour in the production of cookies and the prospect of utilizing the cookies as functional food. Cookies were formulated using dried and fermented *Vitex doniana* leaf in the ratio of 1:1. This include; the control, cookies with 100 g of wheat flour and no *Vitex doniana* leaf flour (WLC_1), cookies with 95 g of wheat flour + 5 g *Vitex doniana* leaf flour (WLC_2), cookies made with 90 g of wheat flour +10 g *Vitex doniana* leaf flour (WLC_3), and cookies formulated with 85 g of wheat flour +15 g *Vitex doniana* leaf flour (WLC_4). The physical and chemical properties, α-amylase and α-glucosidase inhibitory activities along with the glycemic index of the *Vitex doniana* leaf flour and wheat-*Vitex doniana* cookies produced were investigated. The cookies produced with 85 g of wheat flour +15 g *Vitex doniana* leaf flour had the highest protein (23.03%), fibre (6.46%), ash (33.3%) and fat content (29.80%) compared to the other formulated cookies. The cookies also demonstrated a strong inhibitory effect against α-amylase (19.8%-38.0%) and α-glucosidase (42.0%-76.0%) enzymes both of which are linked to type 2 diabetes mellitus. In addition, the incorporation of the processed *Vitex doniana* leaf flour in the cookies brought about a significant reduction in the glycemic index of the formulated cookies. In conclusion the results obtained in this study suggests that the supplementation of wheat flour with *Vitex doniana* leaf flour in the production of cookies could be contemplated as a functional food.

Key words: glycemic index; α-amylase; α-glucosidase; functional foods; antioxidant

Introduction

Functional foods can be defined as any food confirmed to have a health promoting or disease preventing property beyond the basic functions of supplying nutrient to the body (Martirosyan and Singh, 2015). Functional foods are known to contain high amounts of health promoting bioactive compounds and they are found in both plants and animals, but plants are more highly valued because they have the ability to synthesize phytochemicals which are beneficial to human health. The plant-based functional foods include fruits and vegetables, whole grains, fortified or enhanced foods, beverages, and dietary supplements (Jones and Varady, 2008; Schwager et al., 2008).

Diabetes mellitus (DM) is a metabolic disorder with a significantly high morbidity and mortality rate. It is caused either by deficiency in insulin secretion or degradation of secreted insulin (Cao et al., 2012), which is the result of cell alterations caused by many internal and external factors, such as obesity, sedentary lifestyle, and oxidative stress (Mamun et al., 2014; Ullah et al., 2016). It is characterized by hyperglycemia in postprandial and/or fasting state, and its severe form is accompanied by ketosis and protein wasting along with a number of complications such as retinopathy, neuropathy and peripheral vascular insufficiencies (Chehade and Mooradian, 2000).

There are number of natural products available that are helpful in controlling the progression of diabetes mellitus. Some of which include hundreds of plants which are being used as herbal remedies (Abo et al., 2008). The anti-diabetic potential of these plants are often attributed to the functional ingredients in them such as the dietary fiber (Onwulata et al., 2010; Trinidad et al., 2010). Another anti-diabetic potential of these plants is the ability to inhibit the enzymes associated with carbohydrate metabolism which in turn helps to modulate glucose and insulin response in human body (Tundis et al., 2010).

Vitex doniana of the genus Vitex which belongs to the family of Verbenaceae approximately includes 270 known species of trees and perennial shrub which are widely distributed in tropical West Africa and some East African countries. It is also present in some parts of Nigeria such as, Kogi, Benue, and parts of the savannah regions of Kaduna, Sokoto and Kano states (Yakubu et al., 2014). It is commonly called Vitex (English), Dinya (Hausa), Dinchi (Gbagyi), Uchakoro (Igbo), Oriri (Yoruba) Ejiji (Igala), Olih (Etsako) and Hulugh (Tiv) (Burkill, 2000). Mohammed et al. (2016) reported that the aqueous leaf extract of V. doniana was a strong inhibitor of α-amylase and α-glucosidase which are the key enzymes in carbohydrate digestion. Another study by Nwogo et al. (2013) reported a lowering of the fasting blood glucose in diabetic rat after the administration of V. doniana leaf extract at a dose of 250-750 mg/kg for five days. This is an indication that the extract contains bioactive compounds with potent antidiabetic property.

The essence of this study is to investigate the nutritional and anti-diabetic potential of cookies made from blends of processed V. doniana leaf flour and wheat flour.

Materials and methods

The young leaves of Vitex doniana were purchased from Gboko main market, Benue State, Nigeria in January, 2020. The leaves were identified and authenticated in the Department of Crop Science and Pest Management, Federal University of Technology Akure, Nigeria. All the chemical reagents used were of analytical grade.

Methods

Dry leaf sample preparation

Fresh Vitex doniana leaves were air dried at 28 ± 2 °C on a cleaned laboratory table for one week in the Food Science and Technology food processing laboratory of the Federal University of Technology Akure. After which the leaves were milled into powder with a laboratory blender (model: binatone) and sieved using a 2.0 mm stainless steel fine-mesh kitchen sieve.

Fermented leaf sample preparation

Fresh leaves of Vitex doniana were fermented according to the method described by Ifesan et al. (2014). Salt was separately added to the sample (2 g of salt to 100 g of vegetable) and mixed thoroughly before packing it into a plastic bucket which was covered tightly to serve as a fermentation jar. Fermentation was allowed to proceed at room temperature for three days, after which the leaves were air dried at 28 ± 2 °C on a cleaned laboratory table for two weeks in the Food Science and Technology food processing laboratory of the Federal University of Technology Akure. It was then milled with a laboratory blender (model: binatone) and sieved using a 2.0 mm stainless steel fine-mesh kitchen sieve.

Production of cookies

Four samples of cookies were formulated as presented in Table 1, where varying percentage of wheat flour was replaced with the leaf flour comprising of 50% dry Vitex doniana and 50% fermented Vitex doniana. The formulations include; the control cookies with 100 g of wheat flour and no leaf flour (WLC_1), cookies with 95 g of wheat flour and 5 g of leaf flour (WLC_2), cookies with 90 g of wheat flour and 10 g of leaf flour (WLC_3), and cookies with 85 g of wheat flour and 15 g of leaf flour (WLC_4). The cookies were produced as described by Ifesan and Ebosele (2017), using flour (wheat or wheat + leaf flour), sugar, margarine, salt, sodium bicarbonate, water, milk and vanilla essence which were all weighed appropriately and the two stage creaming up method was used. All the ingredients except for flour were mixed thoroughly in a Kenwood mixer (a 3-speed hand mixer), it was then transferred into a bowl and the flour and sodium bicarbonate was added with continuous mixing for 15 min until smooth dough was obtained. A piece of this dough was cut, placed on a clean platform and then rolled out using rolling pin until the desired uniform texture and thickness was obtained. Cookies cutter was used to cut the sheet of the dough into the required shapes and sizes. These were then transferred on to a greased (with margarine) baking tray. The baking was done at 200 ºC for 15-20 min, after which the hot cookies was removed from the pan and placed on a clean tray to cool down. The cookies were packed in polyethylene sachets of appropriate thickness and permeability, sealed and then kept at room temperature for further analyses.

Chemical analyses of processed Vitex doniana leaf flour and formulated cookies

The proximate analysis was determined using the standard analytical techniques of Association of Official Analytical Chemists (AOAC, 2012) and the DPPH was determined using the method of Zhang and Hamauzu (2004).

Ingredients	WLC_1	WLC_2	WLC_3	WLC_4
Wheat flour (g)	100	95	90	85
V. doniana flour (g)	0	5	10	15
Sugar (g)	10	10	10	10
Margarine (g)	30	30	30	30
Salt (g)	2	2	2	2
Sodium bicarbonate (g)	1	1	1	1
Milk (g)	10	10	10	10
Water (ml)	50	50	50	50
Vanilla essence (ml)	2	2	2	2

WLC_1= cookies with 100 g of wheat flour and no leaf flour (control sample)
WLC_2 = cookies with 95 g of wheat flour and 5 g leaf flour (sample 1)
WLC_3 = cookies with 90 g of wheat flour and 10 g leaf flour (sample 2)
WLC_4 = cookies with 85 g of wheat flour and 15 g leaf flour (sample 3)
Source; (Ifesan and Ebosele, 2017).

Table 1: *Formulation of wheat-Vitex doniana cookies*

Physical analysis of the formulated cookies

The weight (W) of the cookies was measured on a weighing balance while the diameter (D), thickness (T) and spread ratio were analysed as described by Ganorkar and Jain (2014).

Evaluation of alpha-amylase inhibitory activities of mixture of dried and fermented Vitex doniana leaf flour and formulated cookies

This assay was carried out using a modified procedure of McCue and Shetty (2004). A total of 250 µl of each sample was placed in a tube and 250 µl of 0.02 M sodium phosphate buffer containing α-amylase solution of 0.5 mg/ml was added. This solution was pre incubated at 25 °C for 10 min, after which 250 µl of 1% starch solution in 0.02 M sodium phosphate buffer was added at regulated intervals and then further incubated at 25 °C for 10 min. The reaction was terminated by adding 500 µl of dinitrosalicylic acid (DNS) reagent. The tubes were then incubated in boiling water for 5 min and cooled to room temperature. The reaction mixture was diluted with 5 ml distilled water and the absorbance was measured at 540 nm using spectrophotometer. A control was prepared using the same procedure replacing the extract with distilled water. The α-amylase inhibitory activity was calculated as percentage inhibition using equation 1:

$$\%\ \alpha - \text{amylase Inhibition} = \frac{\text{Abs}_{\text{control}} - \text{Abs}_{\text{extract}}}{\text{Abs}_{\text{control}}} \times 100 \qquad (\text{Eq } 1)$$

Evaluation of alpha-glucosidase inhibitory activities of mixture of dried and fermented Vitex doniana leaf flour and formulated cookies

The effect of each sample on α-glucosidase enzyme was determined according to the method described by Kim et al. (2005), using α-glucosidase from Saccharomyces cerevisiae. The substrate solution p-nitrophenylglucopyranoside (pNPG) was prepared in 20 mM phosphate buffer, and pH 6.9. Approximately 100 µl of α-glucosidase was pre incubated with 50 µl of the different concentrations of the extracts (acetone, ethanol, and water) for 10 min. Then 50 µl of 3.0 mM (pNPG) as a substrate dissolved in 20 mM phosphate buffer (pH 6.9) was then added to start the reaction. The reaction mixture was incubated at 37 °C for 20 min and stopped by adding 2 ml of 0.1 M Na_2CO_3. The α-glucosidase activity was determined by measuring the yellow-coloured paranitrophenol released from pNPG at 405 nm. The results were expressed as percentage of the blank control. Percentage inhibition was calculated using equation 2:

$$\%\ \alpha - \text{glucosidase Inhibition} = \frac{\text{Abs}_{\text{control}} - \text{Abs}_{\text{extract}}}{\text{Abs}_{\text{control}}} \times 100 \qquad (\text{Eq } 2)$$

Determination of glycemic index of mixture dried and fermented Vitex doniana leaf flour and formulated cookies

In vitro starch hydrolysis rate and GI were determined according to Goni et al (1997). Exactly 50 mg of each sample was incubated with 1 mg of pepsin in 10 ml HCl-KCl buffer (pH 1.5) at 400 ºC for 60 min in a shaking water bath. The digest was diluted to 25 ml by adding phosphate buffer (pH 6.9), and then 5 ml of α-amylase solution containing 0.005 g of α-amylase in 10 ml of buffer was added. The samples were incubated at 37 ºC in a shaking water bath. About 0.1 ml of the sample was taken from each flask and boiled for 15 min to inactivate the enzyme. Sodium acetate buffer (1 ml 0.4 M, pH 4.75) was added and the residual starch digested to glucose by adding 30 ml amyloglucosidase and incubated at 60 ºC for 45 mins. Glucose concentration was determined by adding 200 ml of dinitrosalicylic acid colour reagent. The reaction mixtures were stopped by placing the tubes in a water bath at 100 ºC for 5 min and then cooled to room temperature. The reaction mixture was then diluted by adding 5 ml of distilled water and the mixture was centrifuged at 1200 rmp. The supernatant was collected and the absorbance measured at 540 nm using spectrophotometer. The rate of starch digestion was expressed as the percentage of starch hydrolysed. A 50 mg sample of glucose was used as the standard.

Sensory attributes of wheat-Vitex doniana cookies

Sensory attributes were performed using the method of Ihekoronye and Ngoddy (1985). Forty panelist (staff and students) were used from Federal University of Technology, Akure. The samples were scored for Appearance, Aroma, Taste, Texture, Mouth feel and Overall Acceptability. The participants evaluated the samples using a 9-point hedonic scale quality analysis with 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = Neither like or disliked, 4 = Dislike slightly, 3 = dislike moderately, 2 = Dislike very much, 1 = Dislike extremely.

Statistical analysis

Data was generated in triplicates and analysed using analysis of variance (ANOVA) using SPSS version 23.0 computer program. Means were separated using Duncan Multiple Range Test (DMRT) with 95% confidence level ($p \leq 0.05$). The results were expressed as mean ± standard deviation (Steel and Torrie, 1980).

Results and Discussion

Proximate composition of blends of dried and fermented Vitex doniana leaf flour and formulated cookies

The proximate composition of Vitex doniana leaf and formulated cookies in Table 2 shows that the V. doniana leaf flour (CVD) had the highest moisture content of 11.92% followed by the control cookies with 100 g of wheat flour and no leaf flour WLC_1 (3.96%), cookies with 85 g of wheat flour and 15 g of leaf flour WLC_4 (3.87%), cookies with 90 g of wheat flour and 10 g of leaf flour (WLC_3) 3.60% and cookies with 95 g of wheat flour and 5 g of leaf flour WLC_2 (3.14%). The moisture content of the cookies is dependent on the time and temperature used for the baking process and the moisture content obtained in this study was found to be within the acceptable limit for baked goods with respect to storage stability and microbial contamination. The ash content (9.74%) was highest in the V. doniana leaf flour CVD and lowest (1.31%) in the control cookies WLC_1, however there was no significant difference ($p > 0.05$) between samples WLC_2 (2.83%), WLC_3 (3.11%) and WLC_4 (3.33%) which were formulated with 5 g, 10 g and 15 g of V. doniana leaf flour respectively. The V. doniana leaf flour (CVD) had the lowest fat content of 3.60% while the cookies with 85 g of wheat flour and 15 g of leaf flour (WLC_4) had the highest fat content of 29.80% but there were also no significant differences ($p > 0.05$) between the cookies formulated with 5 g, 10 g and 15 g V. doniana flour WLC_2 (28.44%), WLC_3 (28.81%) and WLC_4 (29.80%) respectively. It was observed that the fibre content in the formulated cookies increased with increase in the amount of V. doniana leaf flour (5 g, 10 g and 15 g) used in samples WLC_2 (3.30%) WLC_3 (4.57%) and WLC_4 (6.46%). However, the fibre content was highest in the V. doniana leaf flour (CVD) 16.24% and lowest in the control cookies (WLC_1) 2.73%. The high fibre content of the formulated cookies obtained in this study may be beneficial for consumers struggling with diabetes mellitus as well as those that are obese since fibre is not completely broken down by the body and can help to control the deposition of glucose in the blood and also prevent constipation. A progressive increase in the protein content of WLC_2 (8.13%), WLC_3 (15.92%) and WLC_4 (23.03%) was observed with increase in the amount of V. doniana leaf flour (5 g, 10 g and 15 g) added to the formulated cookies. The protein content recorded in this study was highest in the V. doniana leaf flour (CVD) 28.73% and lowest in the control cookies (WLC_1) 4.46%. There was significant decrease in the carbohydrate content with increase in the amount of V. doniana leaf flour (5 g, 10 g and 15 g) added into sample WLC_2 (52.82%), WLC_3 (44.37%) and WLC_4 (33.51%) respectively. However, the carbohydrate content was found to be highest in the control cookies (WLC_1) 63.46% and lowest in the V. doniana leaf flour (CVD) 29.77%. The energy value of the V. doniana leaf flour (CVD) was 266.40 Kcal/100g while that of the control cookies (WLC_1) was 488.49 Kcal/100g. However, the energy values of the formulated cookies ranged from 494.36 Kcal/100g to 500.45 Kcal/100g and was found to be higher than the FAO daily recommended energy values for adults which is 344 kcal /day.

Proximate	WLC_1	WLC_2	WLC_3	WLC_4	CVD
Moisture	$3.96^{b}\pm0.06$	$3.14^{d}\pm0.02$	$3.60^{c}\pm0.01$	$3.87^{b}\pm0.00$	$11.92^{a}\pm0.06$
Crude Ash	$1.31^{c}\pm0.34$	$2.83^{b}\pm0.05$	$3.11^{b}\pm0.01$	$3.33^{b}\pm0.00$	$9.74^{a}\pm0.60$
Crude Fat	$24.09^{b}\pm0.72$	$28.44^{a}\pm1.06$	$28.81^{a}\pm0.42$	$29.80^{a}\pm1.51$	$3.60^{c}\pm0.30$
Crude Fibre	$2.73^{d}\pm0.06$	$3.30^{d}\pm0.00$	$4.57^{c}\pm0.05$	$6.46^{b}\pm0.13$	$16.24^{a}\pm0.48$
Protein	$4.46^{e}\pm0.10$	$8.13^{d}\pm0.18$	$15.92^{c}\pm0.62$	$23.03^{b}\pm1.01$	$28.73^{a}\pm0.39$
Carbohydrate	$63.46^{a}\pm0.17$	$52.82^{b}\pm1.30$	$44.37^{c}\pm0.42$	$33.51^{d}\pm0.73$	$29.77^{e}\pm0.93$
Energy	$488.49^{d}\pm0.33$	$499.76^{b}\pm0.85$	$500.45^{a}\pm0.49$	$494.36^{c}\pm1.08$	$266.40^{e}\pm0.54$

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at $p<0.05$.
WLC_1: cookies with 100 g of wheat flour and no leaf flour (control); WLC_2: cookies with 95 g of wheat flour and 5 g leaf flour; WLC_3: cookies with 90 g of wheat flour and 10 g leaf flour; WLC_4: cookies with 85 g of wheat flour and 15 g leaf flour; CVD: Vitex doniana leaf flour.

Table 2: *Proximate (%) and energy (Kcal/100g) composition of mixture of dried and fermented Vitex doniana leaf flour and formulated cookies*

Physical assessments of wheat-Vitex doniana cookies

The mean values of the weight, diameter, height and spread ratio of the formulated cookies is presented in Table 3. A significant increase in the weight of the control cookies (5.65 g) was observed compared to the cookies formulated with 5 g, 10 g and 15 g of V. doniana leaf flour (WLC_2) 5.02 g, (WLC_3) 4.93 g and (WLC_4) 3.21 g respectively. The decrease in weight of the formulated cookies obtained in this study is in agreement with the findings of Mahmoud (2017) who also reported decrease in weight with increase in supplementation of Eucalyptus leaf powder in cookies. There was no significant difference ($p > 0.05$) between the diameter of the control cookies (WLC_1) 3.85 cm, cookies with 5 g of V. doniana leaf flour (WLC_2) 3.79 cm and cookies with 10 g of V. doniana leaf flour (WLC_3) 3.55 cm. However, there was a decrease in the diameter of the cookies with 15 g of V. doniana leaf flour (WLC_4) 3.32 cm and this is in harmony with the reports of Rabie et al. (2020). The height of the formulated cookies showed no significant difference ($p > 0.05$) between the control cookies (WLC_1) 0.39 cm and the cookies with 5 g of V. doniana leaf flour WLC_2 (3.79 cm), cookies with 10 g of V. doniana leaf flour (WLC_3) 0.32 cm and the cookies with 15 g of V. doniana leaf flour (WLC_4) 0.30 cm. There was a progressive decrease in the height, weight and diameter of the cookies with increase in the amount of V. doniana leaf flour incorporated. It was observed that there was also a progressive increase in spread ratio values with corresponding increase in the amount of V. doniana leaf flour added to the cookies and this is in line with the documentation of Singh et al. (2003) and Igbabul et al. (2018) who reported an increase in spread ratio of cookies with increase in non-wheat protein content. However, there was no significant difference ($p > 0.05$) in the spread ratio of the control cookies (WLC_1) 10.47 cm, cookies with 5 g of V. doniana leaf flour (WLC_2) 10.97 cm, cookies with 10 g of V. doniana leaf flour (WLC_3) 11.28 cm and the cookies with 15 g of V. doniana leaf flour (WLC_4) 11.60 cm.

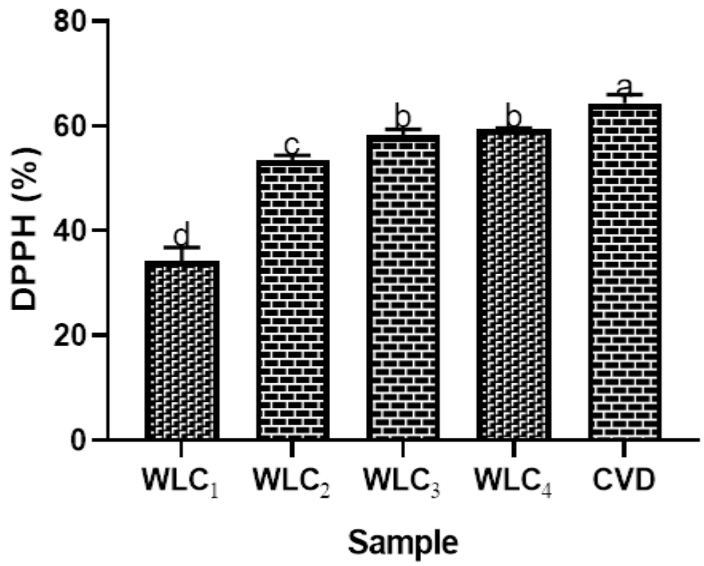
Determinations	WLC_1	WLC_2	WLC_3	WLC_4
Weight (g)	$5.65^{a}\pm0.23$	$5.02^{b}\pm0.13$	$4.93^{b}\pm0.30$	$3.21^{c}\pm0.05$
Diameter (cm)	$3.85^{a}\pm0.16$	$3.79^{a}\pm0.16$	$3.55^{ab}\pm0.15$	$3.32^{b}\pm18$
Height (cm)	$0.39^{a}\pm0.02$	$0.38^{a}\pm0.00$	$0.32^{b}\pm0.00$	$0.30^{b}\pm0.03$
Spread ratio (cm)	$10.47^{b}\pm0.80$	$10.95^{b}\pm0.86$	$11.28^{a}\pm0.93$	$11.69^{a}\pm0.80$

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at $p<0.05$.
WLC_1: cookies with 100 g of wheat flour and no leaf flour (control); WLC_2: cookies with 95 g of wheat flour and 5 g leaf flour; WLC_3: cookies with 90 g of wheat flour and 10 g leaf flour; WLC_4: cookies with 85 g of wheat flour and 15 g leaf flour.

Table 3: *Physical characteristics of wheat-Vitex doniana cookies*

Antioxidant properties of mixture of dried and fermented Vitex doniana leaf flour and formulated cookies

The antioxidant properties of Vitex doniana leaf and formulated cookies in Figure 1 shows that the V. doniana leaf flour (CVD) had the highest free radical scavenging ability of 64.27% against DPPH followed by the cookies formulated with 15 g, 10 g and 5 g of V. doniana leaf flour (WLC_4) 59.53%, (WLC_3) 58.17% and (WLC_2) 53.51% respectively. However, there was no significant difference ($p > 0.05$) between the antioxidant ability of the cookies formulated with 10 g and 15 g of V. doniana leaf flour. The least free radical scavenging ability of 34.24% was observed in the control cookies (WLC_1). The increase in the antioxidant activity of the formulated cookies with corresponding increase in the amount of V. doniana leaf flour observed in this study coincides with the findings of Mahmoud (2017), Ashoush and Mahdy (2019) and Rawung et al. (2021). The results obtained in this study demonstrates that the incorporation of V. doniana in our diet could be beneficial to health with respect to free radical scavenging.

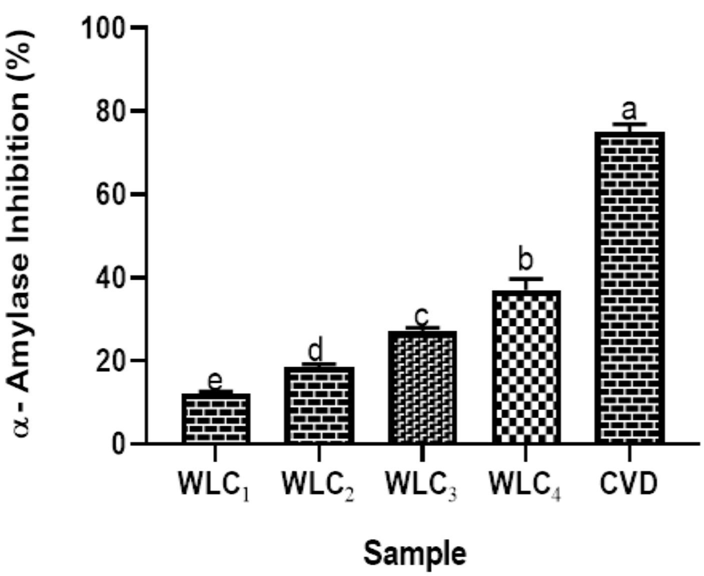


WLC1: cookies with 100 g of wheat flour and no leaf flour (control); WLC2: cookies with 95 g of wheat flour and 5 g leaf flour; WLC3: cookies with 90 g of wheat flour and 10 g leaf flour; WLC4: cookies with 85 g of wheat flour and 15 g leaf flour; CVD: mixture of dried and fermented Vitex doniana laf flour.

Figure 1: *2,2-diphenyl-1-picrylhydrazyl (DPPH) (%) of mixture of dried and fermented Vitex doniana leaf flour and formulated cookies.*

Inhibitory activity of mixture of dried and fermented Vitex doniana leaf flour and formulated cookies on α-amylase enzyme

The effect of Vitex doniana leaf and the formulated cookies on α-amylase enzyme presented in Figure 2 shows that the V. doniana leaf flour (CVD) 75.06% had the highest inhibitory effect on α-amylase enzyme, this result is in line with the findings of Mohammed et al. (2016) and Ani et al. (2020) who both reported that the aqueous leaf extract of V. doniana was a strong inhibitor of α-amylase enzyme. With respect to the formulated cookies, there was a progressive increase in the inhibitory effect on α-amylase enzyme with increase in the amount of V. doniana leaf flour. It was also observed that the control cookies (WLC1) 12.15% had the least inhibitory effect on α-amylase enzyme. The cookies formulated with 15 g of V. doniana leaf flour (WLC4) had the highest inhibitory effect on α-amylase enzyme and this may present it as an agent that could perform a fundamental role in the management of type two diabetes mellitus.

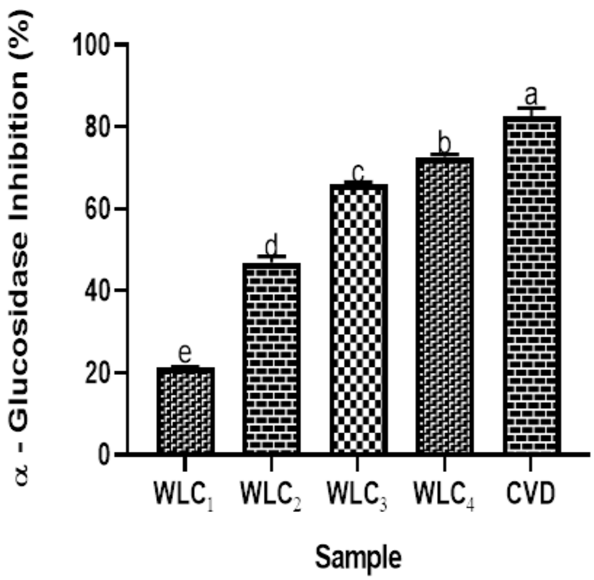


WLC_1: cookies with 100 g of wheat flour and no leaf flour (control); WLC_2: cookies with 95 g of wheat flour and 5 g leaf flour; WLC_3: cookies with 90 g of wheat flour and 10 g leaf flour; WLC_4: cookies with 85 g of wheat flour and 15 g leaf flour; CVD: mixture of dried and fermented Vitex doniana leaf flour.

Figure 2: *α- amylase inhibition (%) of mixture of dried and fermented Vitex doniana leaf flour and formulated cookies.*

Inhibitory activity of mixture of dried and fermented Vitex doniana leaf flour and formulated cookies on α-glucosidase enzyme

The Vitex doniana leaf flour (CVD) exhibited the highest inhibitory effect of 82.58% on α-glucosidase enzyme followed by the cookies formulated with 15 g of V. doniana leaf flour (WLC_4) 72.65%, the cookies with 10 g of V. doniana leaf flour (WLC_3) 66.10%, the cookies formulated with 5 g of V. doniana leaf flour (WLC_2) 46.88% and the control cookies (WLC_1) 21.28% as shown in Figure 3. The high inhibitory effect of the V. doniana leaf flour (CVD) obtained in this study is in agreement with the findings of Mohammed et al. (2016) who reported that the aqueous leaf extract of V. doniana displayed a high inhibitory activity against α-glucosidase enzyme.

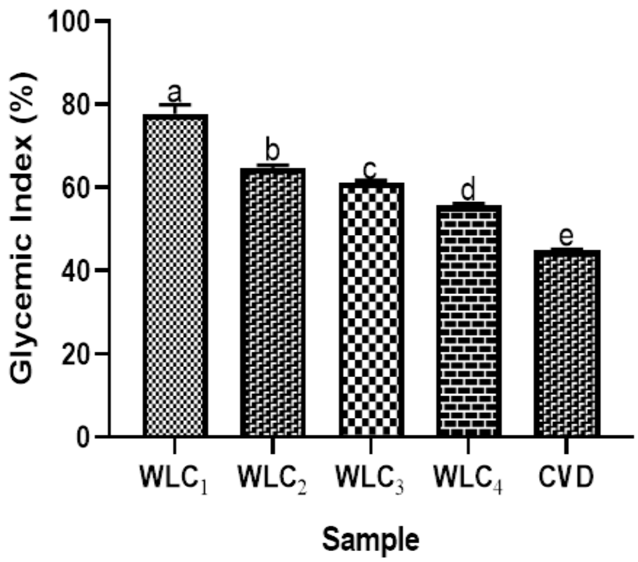


WLC_1: cookies with 100 g of wheat flour and no leaf flour (control); WLC_2: cookies with 95 g of wheat flour and 5 g leaf flour; WLC_3: cookies with 90 g of wheat flour and 10 g leaf flour; WLC_4: cookies with 85 g of wheat flour and 15 g leaf flour; CVD: mixture of dried and Vitex doniana leaf flour.

Figure 3: *α- glucosidase inhibition (%) of mixture of dried and fermented Vitex doniana leaf flour and formulated cookies.*

Glycemic index activity of processed Vitex doniana leaf flour and formulated cookies

Carbohydrates are usually grouped according to their glucose postprandial responses, which are commonly classified in terms of high (>70%), medium (56-69%) and low (<55) glycemic index (GI). The postprandial blood glucose levels and the insulin response are dependent on the quality as well as the quantity of carbohydrates intake (Foster-Powell et al., 2002; Atkinson et al., 2008). The in-vitro glycemic index of Vitex doniana leaf and formulated cookies presented in Figure 4 shows that the V. doniana leaf flour (CVD) had the lowest glycemic index of 44.98% while the control cookies (WLC_1) had the highest glycemic index of 77.67%. The glycemic index of the cookies formulated with 5 g, 10 g and 15 g of V. doniana leaf flour were (WLC_2) 64.75%, (WLC_3) 61.28% and (WLC_4) 55.74% respectively and this shows that there was a significant decrease in the glycemic index of the formulated cookies with increase in the amount of V. doniana leaf flour added. The results obtained from this study shows that the cookies formulated with 5 g and 10 g of V. doniana leaf flour could be classified as medium glycemic index, cookies formulated with 15 g of V. doniana leaf flour could be classified as having a low glycemic index while the control cookies is in the range of high glycemic index group. Therefore, cookies formulated with 15 g of V. doniana leaf flour may be the best option with respect to the management of diabetes mellitus



WLC$_1$: cookies with 100 g of wheat flour and no leaf flour (control); WLC$_2$: cookies with 95 g of wheat flour and 5 g leaf flour; WLC$_3$: cookies with 90 g of wheat flour and 10 g of plant leaf flour; WLC$_4$: cookies with 85 g of wheat flour and 15 g leaf flour; CVD: mixture of dried Vitex doniana leaf flour.

Figure 4: *Glycemic index (%) of mixture of dried and fermented Vitex doniana leaf flour and formulated cookies.*

Consumer acceptability of wheat-Vitex doniana cookies

The sensory attributes evaluated in the cookies made from Vitex doniana leaf flour include appearance (5.60-7.70), aroma (6.58-7.25), taste (6.23-6.95), texture (6.55-7.40), mouth feel (6.75-7.65) and overall acceptability (6.45-7.63) as presented in Table 4. It was observed that the panelist preferred the appearance of the control cookies (WLC$_1$) 7.70 (like moderately) compared to the cookies formulated with 5 g, 10 g and 15 g of V doniana leaf flour ranging from 6.48 (like slightly) to 5.60 (Neither like or dislike). This could be attributed to the development of a darker colour as a result of the addition of V. doniana leaf flour which generated a difference from the regular yellowish cream colour. Appearance has been reported to be a fundamental sensory attribute which has the ability to influence consumer acceptability (Ifesan et al., 2009).

Attribute	WLC$_1$	WLC$_2$	WLC$_3$	WLC$_4$
Appearance	$7.70^{a}\pm0.97$	$6.48^{b}\pm1.26$	$6.10^{bc}\pm1.50$	$5.60^{c}\pm1.92$
Aroma	$7.25^{a}\pm1.19$	$6.85^{ab}\pm1.33$	$6.70^{ab}\pm1.32$	$6.58^{b}\pm1.41$
Taste	$6.95^{a}\pm1.40$	$6.60^{ab}\pm1.37$	$6.33^{ab}\pm1.31$	$6.23^{b}\pm1.78$
Texture	$7.40^{a}\pm1.03$	$7.10^{ab}\pm1.01$	$6.73^{b}\pm1.52$	$6.55^{b}\pm1.68$
Mouth feel	$7.65^{a}\pm0.95$	$7.25^{ab}\pm1.10$	$6.98^{b}\pm1.17$	$6.75^{b}\pm1.50$
Overall acceptability	$7.63^{a}\pm0.90$	$6.98^{b}\pm0.95$	$6.53^{b}\pm1.34$	$6.45^{b}\pm1.52$
Mean	7.43^{a}	6.88^{b}	6.56^{c}	6.36^{d}

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at $p<0.05$.
WLC$_1$: cookies with 100 g of wheat flour and no leaf flour (control); WLC$_2$: cookies with 95 g of wheat flour and 5 g leaf flour; WLC$_3$: cookies with 90 g of wheat flour and 10 g leaf flour; WLC$_4$ - cookies with 85 g of wheat flour and 15 g leaf flour.

Table 4: *Consumer acceptability of wheat-Vitex doniana cookies*

There was no significant difference ($p > 0.05$) in the aroma of cookies which ranged from 6.70 to 7.25 and taste from 6.33 to 6.95 in samples WLC$_1$, WLC$_2$ and WLC$_3$ however, all three samples were significantly different ($p < 0.05$) from WLC$_4$ in both aroma 6.58 (like slightly) and taste 6.23 (like slightly). The study also revealed that the texture ranging from 6.55 (like slightly) to 7.40 (like moderately) and the mouth feel from 6.75 (like slightly) to 7.65 (like moderately) of the control cookies (WLC$_1$) was significantly different ($p < 0.05$) from the cookies formulated with V. doniana leaf flour. This could be as a result of the increase in the fibre content of the formulated cookies due to the addition of V. doniana leaf flour which in turn altered the degree of smoothness of the cookies and brought about a noticeable coarseness. The overall acceptability of the control cookies (WLC_1) 7.63 (like moderately) was also significantly different ($p < 0.05$) from cookies formulated with of V. doniana leaf flour ranging from 6.45 to 6.98 (like slightly) and this could very well mean that the consumer acceptability of the wheat +V. doniana cookies were generally above average.

Conclusion

The results obtained in this study shows that the supplementation of processed Vitex doniana leaf flour (dried and fermented in the ratio of 1:1) in the production of cookies demonstrated a positive influence on the nutritional and anti-diabetic properties of the cookies. The sample with 85 g of wheat flour and 15 g of leaf flour had a notable increase in ash, fat, fibre and protein content. It also had a high antioxidant activity and a high inhibitory potential against α-amylase and α-glucosidase enzymes. The glycemic index of the formulated cookies was in the medium to low range and the overall acceptability of the cookies was above average.

Contribution to knowledge

This research has been able to establish that dried and fermented Vitex doniana leaf flour may be employed in the production of functional cookies with anti-diabetic properties.

References

1. Abo K. A., Fred-Jaiyesimi A. A., Jaiyesimi A. E. (2008). Ethnobotanical studies of medicinal plants used in the management of diabetes mellitus in South Western Nigeria. J. Ethnopharmacol. 115(1):67-71.
2. Ani O. N., Udedi, S. C., Anajekwu, B. A., Asogwa, K. K., Ekwealor, K. U. (2020). Inhibitory potential and antidiabetic activity of leaf extracts of Vitex doniana. Afr. J. Biochem. 14(3):72-80.
3. AOAC. (2012). Official methods of analysis.18th Edition, Association of Official Analytical Chemists. Washington.
4. Ashoush, I. S., Mahdy, S. M. (2019). Nutritional Evaluation of Cookies Enriched with Different Blends of Spirulina platensis and Moringa oleifera Leaves Powder. j. food & dairy sci. 10(3): 53-60.
5. Atkinson, F. S., Foster-Powell, K., Brand-Miller, J. C. (2008). International tables of glycemic index and glycemic load values: 2008. Diabetes Care. 31(12):2281-2283.
6. Burkill, H. M., 2000. The useful plants of West tropical Africa. Vol. 5 2nd Edition, page 272-275. Kew, England: Royal Botanic Gardens.
7. Cao, A., Tang, Y., Liu, Y. (2012). Novel fluorescent biosensor for α-glucosidase inhibitor screening based on cationic conjugated polymers. ACS Appl. Mater. Interfaces. 4(8):3773-3778.
8. Chehade, J. M., Mooradian, A. D. (2000). A rational approach to drug therapy of type 2 diabetes mellitus. Drugs. 60(1):95-113.
9. Foster-Powell, K., Holt, S. H., Brand-Miller, J. C. (2002). International table of glycemic index and glycemic load values: 2002. Am. J. Clin. Nutr. 76(1):5-56.
10. Ganorkar, P. M., Jain, R. K. (2014). Effect of flaxseed incorporation on physical, sensorial, textural and chemical attributes of cookies. Int. Food Res. J. 21(4):1515-1521.
11. Goñi, L., García-Alonso, A., Saura-calixto, F. (1997). A starch hydrolysis procedure to estimate glycemic index. Nutr Res. 427-437.
12. Ifesan, B. O., Hamtasin, C., Mahabusarakam, W., Voravuthikunchai, S. P. (2009). Inhibitory effect of Eleutherine americana Merr. extract on Staphylococcus aureus isolated from food. J. Food Sci. 74(1):31-36.
13. Ifesan, B., Ebosele, F. (2017). Chemical properties of watermelon seed and the utilization of dehulled seed in cookies production. Carpathian J. Food Sci. Technol. 9 (1):126-135.
14. Ifesan, B., Egbewole, O. O., Ifesan, B. T. (2014). Effect of Fermentation on Nutritional Composition of Selected Commonly Consumed Green Leafy Vegetables in Nigeria. Int J Appl Sci Biotechnol 2(3):291-297.
15. Igbabul, B., Ogunrinde, D. M., Amove, J. (2018). Proximate, Micronutrient Composition, Physical and Sensory properties of Cookies Produced from Wheat, Sweet Detar and Moringa Leaf Flour Blends. Curr. Res. Nutr. Food Sci. 690-699.
16. Ihekoronye, A. I., Ngoddy, P. O. (1985). Integrated food science and technology for the tropics. 296-301.
17. Jones, P. J., Varady, K. A., 2008. Are functional foods redefining nutritional requirements? Appl Physiol Nutr Metab. 33(1):118-123.
18. Kim, Y. M., Jeong, Y. K., Wang, M. H., Lee, W. Y., Rhee, H. I., 2005. Inhibitory effect of pine extract on alpha-glucosidase activity and postprandial hyperglycemia. Nutrition. 21(6):756-61.
19. Mahmoud, E. A. (2017). Effect of Eucalyptus Leaves Powder on the Nutritional Value and Organoleptic Properties of Cookies. j. food & dairy sci. 8(3):137-143.
20. Mamun-or-Rashid, A., Hossain, S., Hassan, N., Dash, B. K., Sapon, A., Sen, M. K. (2014). A review on medicinal plants with antidiabetic activity. J. pharmacogn. phytochem. 3(4):149-159.
21. Martirosyan, D. M., Singh, J. (2015). A New Definition of Functional Food by FFC: What Makes a New Definition Unique? Funct. Foods Health Dis. 5(6):209-223.
22. McCue, P. P., Shetty, K.(2004). Inhibitory effects of rosmarinic acid extracts on porcine pancreatic amylase in vitro. Asia Pac. J. Clin. Nutr. 13(1):101-106 .
23. Mohammed, A. I., Koorbanally, N. A., Islam, S. (2016). Anti-oxidative, α-glucosidase and α-amylase inhibitory activity of Vitex doniana: Possible exploitation in the management of type 2 diabetes. Acta Pol. Pharm. 73(5):1235-1247.
24. Nwogo, A. O., Kalu, M. K., Uchechukwu, O., Glory, O. (2013). Hypoglycemic effects of Aqueous and Methanolic Leaf Extracts of Vitex doniana on Alloxan Induced Diabetic Albino Rats. J. Med. Sci. 13: 700-707.
25. Onwulata, C. I., Thomas, A. E., Cooke, P. H., Phillips, J. G., Carvalho, C., Ascheri, J., Tomasula, P. M. (2010). Glycemic Potential of Extruded Barley, Cassava, Corn, and Quinoa Enriched With Whey Proteins and Cashew Pulp. Int. J. Food Prop.13, 338–359.
26. Rabie, M. M., Ibrahim, F. Y., Youssif, M. R., Ezz El-Raga, N. M. (2020). Effect of Moringa oleifera Leaves and Seeds Powder Supplementation on Quality Characteristics of Cookies. j. food & dairy sci. 11(2):65-73.
27. Rawung, R. B., Tangel, S. J., Nurkolis, F. (2021). Cookies Rich in Antioxidant from Mango (Mangifera indica) with Binahong (Anredera cordifolia) as a Potential for Postoperative Wound Healing. Ann. Romanian Soc. Cell Biol. 6607-6611.
28. Schwager, J., Mohajeri, M. H., Fowler, A., Weber, P. (2008). Challenges in discovering bioactives for the food industry. Curr. Opin. Biotechnol. 19 (2):66-72.
29. Singh, J., Singh, N., Sharma, T. R., Saxena, S. K. (2003). Physicochemical, rheological and cookie making properties of corn and potato flours. Food Chem. 83(3):387-393.

30. Steel, R. G., Torrie, J. H., 1980. Principles and procedures of statistics. A biometrical approach, 2nd Edition. New York: McGraw-Hill Book Company.
31. Trinidad, T. P., Mallillin, A. C., Loyola, A. S., Sagum, R. S., Encabo, R. R. (2010). The potential health benefits of legumes as a good source of dietary fibre. Br. J. Nutr. 103(4):569-74.
32. Tundis, R., Loizzo, M. R., Menichini, F. (2010). Natural products as alpha-amylase and alpha-glucosidase inhibitors and their hypoglycaemic potential in the treatment of diabetes: an update. Mini Rev Med Chem. 10(4):315-31.
33. Ullah, A., Khan, A., Khan, I., 2016. Diabetes mellitus and oxidative stress-A concise review. Saudi Pharm J . 24(5):547-553.
34. Yakubu, O. E., Nwodo, O., Joshua, P. E., Ugwu, M. N., Odu, A. D., Okwo, F. (2014). Fractionation and determination of total antioxidant capacity, total phenolic and total flavonoids contents of aqueous, ethanol and n-hexane extracts of Vitex doniana leaves. Afr. j. biotechnol. 13(5):693-698.
35. Zhang, D., Hamauzu, Y. (2004). Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. Food Chem. 88(4):503-509.

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