Innovations

Anti-diabetic, Antioxidant and Nutritional Properties of Yoghurt Stabilized with Pumpkin (C. pepo) Pulp Starch

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Abstract: *This study evaluated the antioxidant, antidiabetic and nutritional properties of yogurt containing pumpkin (C. pepo) starch as a stabilizer. Four varieties of yogurt were produced and designated as PY0 (Yoghurt without stabilizer), PY1 (Yoghurt with 1% pumpkin starch), PY2 (Yoghurt with 2% pumpkin starch), PY3 (Yoghurt with 3% pumpkin starch), while PYC is a Commercial yoghurt. The impact of pumpkin starch on the nutritional content, anti-diabetic potential, and anti-oxidant properties of yoghurt was evaluated. Different percentages of pumpkin starch (1%, 2%, and 3%) were used as raw materials. The enriched yogurt showed a significant increase in crude fiber (0.64-0.79%), ash (0.50-0.93%), and carbohydrate content (6.00-9.37%) compared to commercial yogurt and the control. The antidiabetic potential, including α-amylase inhibition (58.82-59.21%) and α glucosidase inhibition (59.52-74.41%), increased with higher percentages of pumpkin starch. The DPPH radical scavenging properties were in the range of 50.80 %-62.81 %, while the ferric-reducing antioxidant properties were in the range of 2.69-10.34 mg/g. the total phenol and flavonoid were at the range 18.35-26.20 mg GAEg^{-1} and 7.51-8.39mgQEg^{-1} respectively. These findings suggest that incorporating pumpkin starch into yogurt production will be a promising approach for enhancing consumer health.*

Keywords: *Antioxidant, antidiabetic, proximate, pumpkin starch, yoghurt.*

1.0. Introduction

Yoghurt is produced through the lactic acid fermentation of milk by adding a starter culture of Streptococcus bulgaricus sub spp. Thermophilus and Lactobacillus delbrueckiisub spp. Bulgaricus (Temesgen and Yetneberk, 2015). Yogurt uses

starch to increase viscosity and influence its texture, creaminess, and mouth feel (Skryploneket al., 2019).
Starch is found in the roots, tubers, and seeds of various plants, they are tasteless, odourless, white polysaccharides. It is formed during photosynthesis in the chloroplasts and amyloplasts of plantsand is stored in plant cells during tuber sprouting, seed germination, and fruit maturation (Tester et al., 2004). In the food industry, starch is used as a food product or as an additive for thickening, preservation, and enhancing quality in baked goods, confectioneries, pasta, soups, sauces, and mayonnaises (Bertolini, 2009). Stabilizers are commonly used in cultured products to control texture and reduce whey separation by providing good resistance to syneresis and a smooth sensation in the mouth through water binding (Amatayakulet al., 2006). Adding stabilizers, such as starch has been found to increase the functionality of yoghurt and plant-based starch has been the cheapest source of stabilizers (Alteminiet al., 2015).
Starch makes up to 60% of the dry weight of pumpkin flesh. (Przetaczek-Roznowskaet al., 2017). The physical and chemical properties of pumpkin starch indicate its potential use in the food industry, especially as a stabilizer. A study on the 1% pumpkin starch addition to yoghurt produced better consumer acceptability (Adetunji, 2024a). The functional and pasting properties of pumpkin (C. pepo) starch have been studied (Adetunji, 2024b). Despite its valuable attributes, pumpkin starch is still underutilized, and its economic potential remains largely unexplored. This study evaluates the nutritional composition, anti-diabetic and anti-oxidant properties of yoghurt stabilized with pumpkin (C. pepo) starch.

2.0. Materials and Method

A full creamed milk, a commercial yoghurt (control) and sugar were bought at a supermarket in Ado-Ekiti, Ekiti State, Nigeria. Yogurt starter (Yobetter, True probiotics) was purchased from Ojodu market, in Lagos, Nigeria. The chemicals used for the analysis were of analytical grade and were obtained from Sigma-Aldrich, London, United Kingdom.

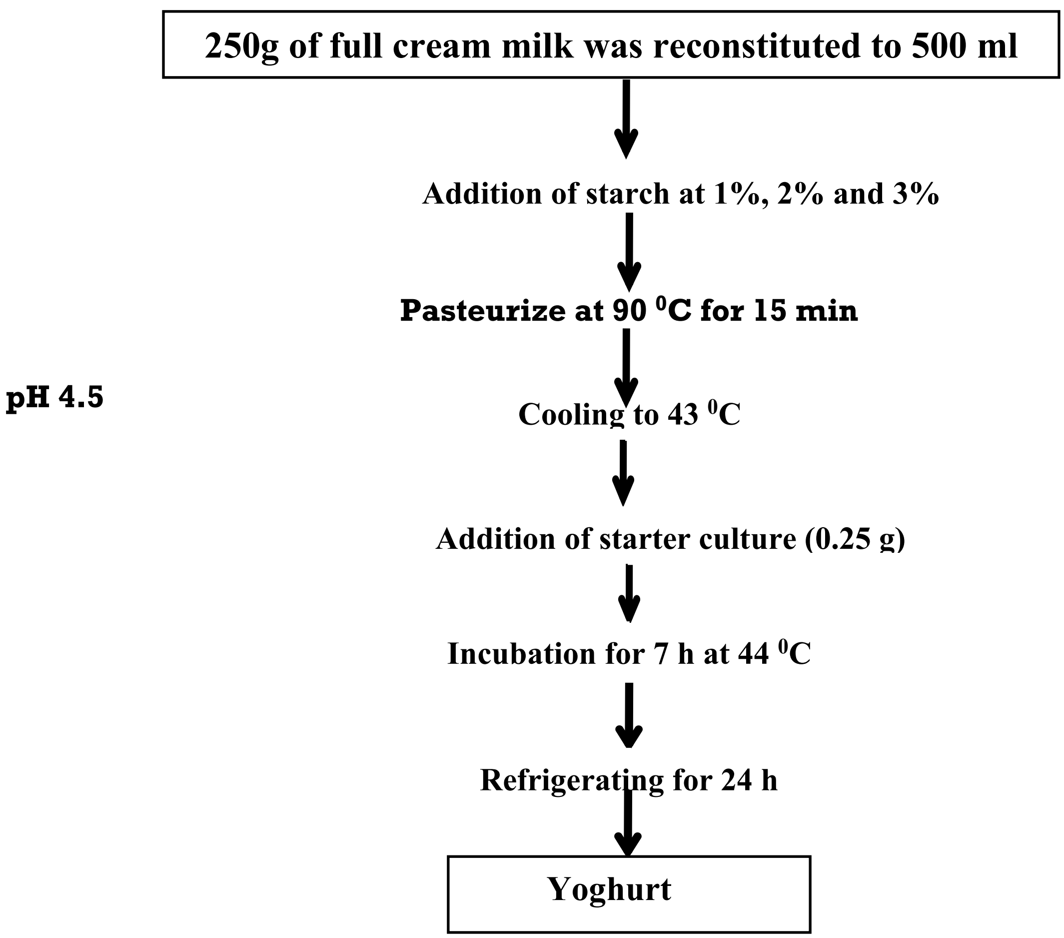
2.1 Production of Pumpkin Starch

One thousand grams of pumpkin pulp were washed with distilled water, milled and dissolved in clean water at room temperature, and then filtered. The residue was discarded while the slurry was centrifuged at 3000 rpm for 15 minutes. The upper sediment was removed and discarded, and the lower sediment containing starch was washed three times with distilled water. The starch was air-dried at room temperature, milled with a Century blender (model: CB-8231-K, AC 220-240 V 50/60 Hz 800 W), and stored in an airtight container at 10°C in a refrigerator for future studies (Adetunji, 2024a).

2.2. Production of Yoghurt stabilized with Pumpkin Starch

The yogurt samples were produced using a modified method based on Adetunji, (2024b) employing pumpkin starch as stabilizers at various ratios of 1%, 2%, and 3% respectively (Krisnaningsihet al., 2018) as shown in Fig. 1.

500g of dried powdered milk was reconstituted with 1000 ml of treated water and heated to 40°C. The samples were divided into four portions and labeled, each of the labeledportions received 50g of sugar, and 1%, 2%, and 3% pumpkin starch were added to each respectively as labelled while the control group received 10g of milk and 50g of sugar. Following this, the samples were pasteurized at 90°C for 15 minutes. After the mixture was cooled to 43°C, it was inoculated with 0.25g of a commercial starter culture containing a pure mixed strain of Lactobacillus bulgaricus and Streptococcus thermophilus. The mixture was carefully stirred to ensure complete dissolution and uniform distribution of the culture granules. The samples were then incubated at about 44°C for 7 hours until curds formed. These curds were gently broken with a hand stirrer to create a smooth, homogenous product, which was then stored in the refrigerator for 24 hours in preparation for further analysis. The yoghurt samples were coded as PY0 (Yoghurt without stabilizer), PY1 (Yoghurt with 1% pumpkin starch), PY2 (Yoghurt with 2% pumpkin starch), PY3 (Yoghurt with 3% pumpkin starch), PYC (Commercial yoghurt).



2.3 Proximate properties of yoghurt

The proximate composition (moisture content, crude fiber, crude fat, total ash, and crude protein contents) of the yoghurt enriched with pumpkin starch were determined by the method of AOAC (2012).

2.4 Determination of antioxidant activities of yoghurt

The ferric-reducing antioxidant property of the extract was determined (Pulido et al., 2000). 0.25 ML of the sample extract was mixed with 0.25 ML of 200 mM of Sodium phosphate buffer pH 6.6 and 0.25 ML of 1% KFC. The mixture was incubated at 50 °C for 20 min, thereafter 0.25 ML of 10% TCA was also added and centrifuged at 2000 x g force for 10 min. Exactly 1 mL of the supernatant was mixed with 1mL of distilled water and 0.1% $FeCl_3$, and the absorbance was measured at 700 nm.

Total flavonoid content was determined by aluminum chloride ($AlCl_3$) colorimetric assay (Bushra et al., 2009) with slight modification. About 500 μl of methanol was added to 10 ml flask containing 500 μl of aqueous extract. To this 50 μl 10% of $AlCl_3$ and 50 μl of 1M of acetic acid (CH_3COOH) was added respectively. The total volume was made up to 2500 μl with distilled water. The solution was then incubated at room temperature for 30 min. Absorbance was read against blank at 415 nm with spectrophotometer (JENWAY 6305, United Kingdom). The flavonoid was calculated using quercetin as standard.

$$\text{Total flavonoid content } \left({}^{\text{mg QE}}/_{\text{g}}\right) = \frac{\text{Abs}_{\text{samp}} \times \text{Conc}_{\text{stand}}\ (\text{mg/ml})}{\text{Abs}_{\text{stand}} \times \text{Conc.}_{\text{samp}}(\text{mg/g})} \qquad \text{Eqn. 1}$$

Abs $_{standard}$ is the absorbance of the solution containing 500 μl quercetin, About 50 μl of 10% $AlCl_3$ and 1M of CH_3COOH. Blank is the mixture of 500 μL of distilled water, 500 μl of methanol, 50 μl distilled water and 1M of CH_3COOH.

The total phenol content (TPC) was determined by Folin–Ciocalteu assay using gallic acid as standard (Singleton et al., 1999). Fifty microliter of aqueous extract of flour sample solution containing 0.5 mg of aqueous extract was dispensed into a test tube, 50 μl of distilled water and 500 μl of Folin–Ciocalteu reagent were added respectively into the test tube and shaken thoroughly. After 3 min, 400 μl of 7.5% sodium carbonate solution was added and the mixture was incubated at 45 °C in a water bath for 40 min and absorbance was measured at 765 nm against the blank. The same procedure was repeated for all standard gallic acid solution (0.1 mg/ml). The blank is a mixture of 100 μl of distilled water, 500 μl of Folin-Ciocalteu reagent and 400 μl of 7.5% sodium carbonate. The total phenolic content was expressed as

gallic acid equivalent per gram of sample (mg of GAE/g sample) through the calibration curve of gallic acid and calculated
as follows;

$$\text{Total phenolic content } \left(\frac{\text{mg GAE}}{\text{g}}\right) = \frac{\text{Abs}_{\text{sample}} \times \text{Conc.}_{\text{standard}}\ (\text{mg/ml})}{\text{Abs}_{\text{standard}} \times \text{Conc.}_{\text{sample}}(\text{g/ml})} \qquad \text{Eqn. 2}$$

The electrons donating ability of the samples were measured from the bleaching of purple coloured methanol solution of DPPH. The spectrometric assay uses the stable radical 2, 2-diphenyl picryhydrazyl (DPPH) as a reagent (Butrits and Bucar, 2000). Twenty microlitre, 40 µl, 60 µl and 80 µl of the aqueous extract (containing 2 mg, 4 mg, 6 mg and 8 mg of the sample respectively) was dispensed into test tubes and made up to 580 µl with distilled water followed by addition of 600 µl of DPPH in methanol and incubated in the dark at room temperature for 15 min. After incubation period, the absorbance was read against blank at 517 nm. The DPPH radical-scavenging capacity (%) was calculated

$$\text{DPPH scavenging} = \frac{\text{Abs}_{\text{Ref}} - (\text{Abs}_{\text{Ref}} - \text{Abs}_{\text{Neg}})}{\text{Abs}_{\text{Ref}}} \text{ x } 100 \qquad \text{Eqn. 3.}$$

2.5 Determination of antidiabetic potentials of yoghurt

The activity of **α** - amylase was carried out according to the method of Oyedemiet al., (2017), based on the starch-iodine colour changes with minor modifications. Soluble starch solution (1%) was used as substrate. The starch solution was prepared by adding 1 g of soluble potato starch in 10 ml water and then boiled for 2 min. After cooling, water was added to reach a final volume of 100 ml. Alpha-amylase solution (0.1 ml of 15 µg/ml in 0.1 M acetate buffer at pH 7.2 containing 0.0032 M sodium chloride) was added to a mixture of 3 ml of 1% soluble starch solution and 2 ml of acetate buffer (0.1 M, pH 7.2) pre-equilibrated at 30 °C in a water bath. 65 Substrate and **α** - amylase blank determinations were undertaken under the same conditions. At zero time (t=0 min) and at the end of the incubation period (t = 60), 0.1 ml of reaction mixture was withdrawn from each tube after mixing and transferred into 10 ml of an iodine solution (0.254 g iodine and 4.0 g potassium iodide). After mixing, the absorbance of the starch-iodine mixture was measured immediately at room temperature using a spectrophotometer at 565 nm. The absorbance of the starch blank was subtracted from the sample reading. One unit of amylase activity was arbitrarily defined as follows: (Ao –At/Ao) × 100, where Ao and At are absorbance of the iodine complex of the starch digest at zero time and after 60 minutes of hydrolysis. Specific activity of **α** -amylase was defined as units/mg protein/60 min. Percentage inhibition was calculated using the equation below.

$$\% \alpha - \text{amylase inhibition} = \left[(\text{Ao} - \text{At})\text{control} - \frac{(\text{Ao} - \text{At})\text{sample}}{\text{Ao} - \text{At}}\right] \times 100 \qquad \text{Eqn. 4}$$

The inhibitory effect of the composite flour on α-glucosidase activity was carried out following the modified method of Pistia-Brueggeman and Hollingsworth (2001). In test-tubes, a reaction mixture containing 500 µl of phosphate buffer (50 mM, pH 6.9), 100 µl of α -glucosidase (1 U/ml), and 200 µl of plant extract of varying concentrations was preincubated for 5 min at 37 °C and then 200 µl of 1 mM PNPG (4-nitrophenyl-Alpha-D-glucopyranoside) substrate was added to the mixture. After further incubation at 37 °C for 30 min, the reaction was stopped by the addition of 500 µl of sodium carbonate (0.1 M). Enzyme, inhibitor, and substrate solutions were all prepared using the same buffer. Acarbose (5 mg/ml) was used as a positive control and water as a negative control. The yellow colour produced (due to 66 pnitrophenol formation) was quantitated by colorimetric analysis and reading the absorbance at 405 nm. Each experiment was performed in triplicate, along with appropriate blanks. The percentage inhibition was calculated using the formula below,

$$\% \alpha - \text{glucosidase inhibition} = \left(\frac{\text{Acontrol} - \text{Asample}}{\text{Asample}}\right) \text{x } 100 \qquad \text{Eqn. 5}$$

2.6 Statistical Analysis

The result was analyzed using SPSS version. 21 (IBM SPSS Statistics, US). The mean and standard deviation of the samples were determined using a One-Way Analysis of Variance (ANOVA) for comparison. The significant difference of all samples analyzed were $p \leq 0.05$ (SPSS, 2011).

3.0 Result and Discussion

Table 1 shows the proximate composition of yogurt enriched with pumpkin starch. Significant differences ($p \leq 0.05$) were noted in the proximate composition of yogurt derived from pumpkin starch compared to the commercial yogurt (PYC) utilized as a control. The moisture content (68.68 – 75.36%). in yogurt formulated from pumpkin starch was lower than commercial yogurt (75.36%) and yogurt without a stabilizer (80.46%). The addition of pumpkin starch significantly decreases the percentage moisture content of yoghurt PY1, PY2 and PY3, due to an increase in the percentage addition of pumpkin starch which agreed with similar findings related to potato starch in stirred yogurt (Okoro and Obi, 2016). Barakat and Hassan (2017), reported a lower moisture value for yoghurt derived from pumpkin flour. According to Codex standards (2010), yogurt is recommended to have a moisture content of less than

84%, suggesting that the low moisture content in yogurt produced from pumpkin starch may lead to desirable texture and mouthfeel.

Table 1: Proximate Composition (%) of Yoghurt Enriched with Pumpkin Starch

Samples	Moisture	Total ash	Crude fat	Crude fibre	Crudeprotein	Carbohydrate
PY0	82.29±0.01^{a}	0.23±0.04^{e}	5.50±0.24^{c}	0.14±0.02^{c}	3.55±0.01^{d}	5.30±0.59^{d}
PY1	72.36±0.11^{c}	0.71±0.01^{b}	6.51±0.70^{b}	0.64±0.03^{b}	5.28±0.23^{c}	6.00±0.46^{c}
PY2	72.00±0.40^{c}	0.93±0.05^{a}	6.47±0.19^{b}	0.78±0.02^{a}	5.84±0.08^{b}	6.68±0.07^{b}
PY3	68.68±0.37^{d}	0.50±0.01^{c}	6.66±0.01^{a}	0.79±0.07^{a}	6.00±0.40^{a}	9.37±0.11^{a}
PYC	75..69±0.04^{b}	0.44±0.10^{d}	3.35±0.01^{d}	0.12±0.08^{c}	2.12±0.02^{e}	9.34±0.02^{a}

Mean ± SD. Values with the same superscript along the same column are not significantly different ($p<0.05$)

Keys: PY0: Yoghurt without stabilizer PY1: Yoghurt with 1% pumpkin starch, PY2: Yoghurt with 2% pumpkin starch, PY3: Yoghurt with 3% pumpkin starch, PYC: Commercial yoghurt.

The total ash content (0.50 – 0.71%) in the yogurt derived from pumpkin starch (PY1 – PY3) was notably higher than the total ash content (0.23 and 0.44%) in yogurt without stabilizer (PY0) and commercial yogurt (PYc) respectively. The ash content of pumpkin starch has been suggested to be1.24%, which is higher than the ash content (0.32%) in cassava starch (Adetunji, 2024b). The elevated total ash content suggested the potential presence of mineral content resulting from adding pumpkin starch in the samples (PY1-PY3), Total ash content in foods represents the residue remaining after organic content is burnt away, leaving behind inorganic minerals (Nesa et al., 2021).

The crude fat content of the samples (PY0, PY1, PY2, PY3, and PYC) was 5.50%, 6.51%, 6.47%, 6.66%, and 3.35%, respectively. Significantly increased crude fat content was observed ($p\leq0.05$) in the yogurt derived from various percentages of pumpkin starch compared to commercial yogurt. The results indicated that as the percentage of pumpkin starch increased, the fat content in the yogurt also increased. The highest crude fat content, obtained in PY3 (6.66%), could be attributed to the 3% substitution of pumpkin starch, the fat content in a pumpkin starch was reported to be 0.84% which was higher than the 0.31% obtained for taro starch (Adetunji, 2024b). Fat plays a crucial role in enhancing the consistency and mouthfeel of yogurt. According to Codex (2010), yogurt should contain less than 15% fat.

The crude protein content (5.28 – 6.00%) observed in the yogurt formulated from pumpkin starch showed a significant increase with the rise in pumpkin starch content. These values were notably higher than the crude protein content (2.12%) in commercial yogurt (PYC) and (3.55%) in yogurt without a stabilizer. Previous reports have indicated that the addition of stabilizers had a more substantial impact on the yogurt compared to the control (Okoro and Obi, 2016). The crude protein content obtained for pumpkin starch-enriched yogurt was notably higher than the range of 2.03 – 4.14% reported by Adelekan and Saleh (2020) for yogurt formulated from Baobab milk and 3.68 – 4.30% reported by Barakat and Hassan (2017) for pumpkin flour yogurt. Previous study had showed that the protein content of pumpkin was 1.75% (Adetunji, 2024b), thus increasing the protein content in the yoghurt. According to Codex standards, yogurt samples should contain no less than 2.70% protein content, as protein provides amino acids, which are essential for promoting growth, development, and tissue repair (McGivern et al., 2021).

The crude fiber content (0.64 – 0.79%) obtained in the pumpkin-yoghurt samples was significantly higher than the crude fiber content in yogurt without a stabilizer (0.14%) and commercial yogurt (0.12%) samples. Furthermore, these values also exceeded the crude fiber content of 0.09 – 0.10% obtained in yogurt samples formulated from baobab milk (Adelekan and Saleh, 2020). Increase in the percentage pumpkin starch addition increases the fibre content of the yoghurt. Dietary fibers play a significant role in human health, contributing to reduced constipation, diabetes prevention, reduced cholesterol levels, and a decreased risk of colorectal cancer (Nweze et al., 2021). Therefore, the high crude fiber value obtained in the yogurt samples is advantageous and may aid in the management of degenerative diseases.

The carbohydrate content in yogurt samples PY0, PY1, PY2, PY3, and PYC were found to be 5.30%, 6.08%, 6.68%, 9.37%, and 9.34%, respectively. There was no significant difference in yoghurt PY3 (9.37%) and commercial yoghurt (9.34%), while there wasa significant decrease in the yoghurt samples PY2, PY1. The yoghurt without stabilizer had the lowestvalue for carbohydrate content. The decrease in carbohydrate content in samples PY1, PY2, compared to the commercial yoghurt agreed with a previous study on potato starch addition in yogurt (Okoro and Obi, 2016). The significant decrease in carbohydrate for PY1 and PY2 in the yoghurt may be due to pumpkin's low glycemic index (Adelerinet al., 2024), thus yoghurt PY1 and PY2may be an ideal food for lactose-intolerant individuals (Ehirim and Ndimantang, 2004). According to The Dairy (2013), yogurt should contain a carbohydrate content below 17.7%. This study revealed that all yogurt samples with pumpkin starch inclusion complied with this standard.

Table 2 described the potential of yoghurt enriched with pumpkin starch to act as an anti-diabetic agent. The percentage of α-amylase inhibition in yoghurt enriched with pumpkin starch PY1, PY2, and PY3 were 58.82%, 59.01%, and 59.21% respectively and were significantly higher than the commercial yoghurt (PYC- 32.10%) and yoghurt without stabilizer (PYO- 38.52). The α-glucosidase inhibition of yoghurt enriched with pumpkin starch PY1 (59.52%), PY2 (60.31%), and PY3 (74.41%) also showed significant differences ($p \leq 0.05$) compared to the commercial control yoghurt (26.40%) and the yoghurt without stabilizer (50.52%). The study suggested that the percentage inhibition of carbohydrate hydrolyzing enzymes increased significantly with the increase in percentage pumpkin starch. The main source of naturally occurring antioxidant is food derived from plant materials because they possess anti-diabetes properties (Shori and Baba, 2011). Previous studies showed that pumpkin has antidiabetic properties and its inclusion in food product could increase the inhibition of hydrolyzing enzymes such as α-amylase and α-glucosidase (Adelerinet al., 2024). These findings suggest that yoghurt enriched with pumpkin starch can inhibit the activities of α-amylase and α-glucosidase enzymes more effectively than yoghurt without stabilizer and commercial yoghurt, this inhibition reduces the rate at which glucose is broken down into sugar and released into the bloodstream. Therefore, yoghurt enriched with pumpkin starch may be a beneficial option for consumers facing challenges related to blood sugar levels.

Table 2: Antidiabetic Properties of Yoghurt Stabilized with Pumpkin Starch

Samples	α-Amylase Inhibition (%)	α-Glucosidase Inhibition (%)
PY0	38.52 ± 0.07^{d}	50.52 ± 0.95^{d}
PY1	58.82 ± 0.21^{c}	59.52 ± 8.28^{c}
PY2	59.01 ± 0.21^{b}	60.31 ± 1.47^{b}
PY3	59.21 ± 0.21^{a}	74.41 ± 0.24^{a}
PYC	32.10 ± 1.61^{e}	26.40 ± 0.17^{e}

Mean ± SD. Values with the same superscript along the same column are not significantly different ($p \leq 0.05$)

Keys: PY0: Yoghurt without stabilizer, PY1: Yoghurt with 1% pumpkin starch, PY2: Yoghurt with 2% pumpkin starch, PY3: Yoghurt with 3% pumpkin starch, PYC: Commercial yoghurt.

Table 3 presents the antioxidant activities of yoghurt enriched with pumpkin starch. The flavonoid content of 7.51 mg QEg^{-1}, 8.04 mg QEg^{-1}, and 8.39 mg QEg^{-1} were found in PY1, PY2, and PY3, respectively, which were significantly higher compared to yoghurt samples PY0 (6.49 mg QEg^{-1}) and PYC (6.90 mg QEg^{-1}). The increase in flavonoid content in PY1, PY2, and PY3 may be attributed to different ratios of pumpkin starch added to the yoghurt, previous studies suggested that pumpkin is a source of many bioactive compounds (Adelerinet al., 2022).

This study shows significant differences ($p \leq 0.05$) in the total phenol content. The total phenol content (18.35-26.20 mg GAEg-1) of yoghurt enriched with pumpkin starch was higher compared to the total phenol content of yoghurt without stabilizer (14.35 mg GAEg-1) and commercial yoghurt (12.68 mg GAEg-1). It was observed that yogurt with 3% pumpkin starch had the highest percentage of total phenol content (26.20 mg GAEg-1), while the yogurt sample with the least total phenol content (18.35 mg GAEg-1) was obtained for commercial yoghurt (PYC). Phenolic compounds are known for their health benefits, especially in preventing chronic diseases such as cancer (Hervert-Hernández et al., 2009). Therefore, supplementing yoghurt with phenolic compounds like pumpkin starch may optimize the health benefits of yoghurt.

Significant increase was observed in the DPPH radical scavenging activity and the ferric-reducing antioxidant properties of yogurt with 1%, 2%, and 3% pumpkin starch addition compared to the commercial yoghurt and yoghurt without stabilizer. Thie increase may be due to the antioxidant properties present in pumpkin (Adelerinet al., 2022). Nikitina et al. (2021) reported an increase in the DPPH radical scavenging activity of skimmed varenets mixed with potato starch. Antioxidants such as DPPH can be used to measure the ability of samples to scavenge free radicals and reduce the risk of chronic diseases such as cancer and heart disease (Bohn, 2019).

Table 3: Antioxidant Properties of Yoghurt stabilized with Pumpkin Starch

Samples	Flavonoid (mg QEg^{-1})	Total phenol (mg $GAEg^{-1}$)	DPPH (%)	FRAP (mg/g)
PY0	6.49 ± 1.65^{e}	14.35 ± 0.07^{d}	28.19 ± 4.86^{d}	2.28 ± 0.08^{d}
PY1	7.51 ± 0.05^{c}	18.35 ± 1.24^{c}	50.80 ± 1.34^{c}	2.69 ± 0.28^{c}
PY2	8.04 ± 0.53^{b}	24.50 ± 0.74^{b}	53.01 ± 0.89^{b}	4.40 ± 1.63^{b}
PY3	8.39 ± 0.85^{a}	26.20 ± 2.67^{a}	62.81 ± 5.81^{a}	10.74 ± 0.71^{a}
PYC	6.90 ± 0.37^{d}	12.68 ± 0.36^{e}	16.30 ± 0.91^{e}	2.14 ± 0.24^{e}

Mean ± Values with the same superscripts along the same column are not significantly different ($p<0.05$)

Keys: PY0: Yoghurt without stabilize, PY1: Yoghurt with 1% pumpkin starch, PY2: Yoghurt with 2% pumpkin starch, PY3: Yoghurt with 3% pumpkin starch, PYC: Commercial yoghurt

4.0. Conclusion

Yoghurt enriched with pumpkin starch exhibited elevated protein, fiber, and ash levels. The samples also displayed enhanced antioxidant properties and effectively inhibited glucose-hydrolyzing enzymes. Consequently, yogurt formulated with a substantial quantity of pumpkin starch may be classified as a functional food which promotes improved health. Advancing the utilization of pumpkin starch as a stabilizing agent in yogurt production would further augment its nutritional characteristics.

5.0. Recommendation

Further studies should be done to purify and characterize the pumpkin pulp starch

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