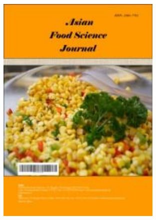

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Physicochemical Properties, Sensory Acceptance and Storage Stability of Yogurt Flavored with Refractance Window Dried Passion Fruit Powder

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Authors' contributions

This work was carried out in collaboration among all authors. Author AA designed the study, performed the data collection, statistical analysis, managed literature searches, wrote the draft of the manuscript and addressed comments. Authors JBK and JM supervised the study and made reviews and corrections in the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The study evaluated the use of refractance window dried passion fruit powder as a flavoring for yogurt.
Place and Duration of Study: Department of Food Technology and Nutrition, Makerere University, Kampala-Uganda between October 2020 and January 2021.
Methodology: Passion fruit pulp was mixed in carboxymethyl cellulose and dried using a laboratory refractance window drier.
Plain yogurt was flavored with 2% passion fruit powder. Passion fruit flavored, plain and commercial yogurt were analyzed for physico-chemical and sensory properties. Statistical analyses were performed using XLSTAT and all results were considered to be significant at $P<0.05$.
Results: pH values and titratable acidity for all yogurts ranged from 4.67 to 3.77 and 1.21% to 2.89%, respectively throughout the 14 day storage period. The apparent viscosity of all yogurts increased significantly during storage and ranged from 413.76 cP to 525.20 cP, the syneresis of

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yogurts ranged from 25.6% to 32.2%, vitamin C content of the yogurts ranged from 0.69 mg/100 g to 1.91 mg/100 g, the carotenoid content of yogurts ranged from 0.55 µgRAE to 1.07 µgRAE, phenolic content of the yogurts ranged from 0.50 mg/100 g GAE to 8.01 mg/100 g GAE, whereas total antioxidant activity of the yogurts ranged from 0.21mg/100g VCE to 9.96mg/100g VCE. For all yogurt types, there was no significant change ($p<0.05$) in any of the sensory parameters (flavor, color, mouth feel, consistency, taste and overall acceptability) over the storage period of 14 days.

Conclusion: Addition of passion fruit powder to yogurt resulted in increased levels of vitamin C, beta carotenoid, total phenolic content and total antioxidant activity, in comparison to plain yoghurt and commercial vanilla flavored yogurt. This will provide consumers with more nutritious options thereby improving nutrition of consumers.

Keywords: Passion fruit; refractance window drying; phytochemicals; shelf stability.

1. INTRODUCTION

Passion fruit (*Passiflora edulis*) is native to tropical America [1] and is mostly grown in tropical and sub-tropical parts of the world [2]. The fruit is valued for its pronounced flavor and aroma which help not only in producing a high quality squash but also in flavoring several other products [3]. It contains several components such as acids, sugars and nutrients that make passion fruit a tasteful and healthy addition to diet [4].

According to Angélica et al. [5], fruits and fruit products like passion fruit pulp have high water content, which makes them very susceptible to decomposition by micro-organisms as well as chemical and enzymatic reactions. These products are extremely perishable and as much as 40% is lost postharvest [6]. Because of the high postharvest losses and the resulting nutritional and economic losses, appropriate postharvest preservation techniques are needed to mitigate this problem [7]. The conversion of passion fruit pulp into a dried form would extend its shelf-life, preventing postharvest loss [8]. Despite drying being an efficient way to preserve fruits, most of the technologies that have been used for drying of passion fruit into powder like spray drying [3,8] and foam mat drying [9] entail application of high temperatures and long drying times which leads to discoloration and loss of flavor compounds, nutrients and bioactive compounds [5]. Refractance window drying technology (RWDT) is fast and products are exposed to relatively low temperatures [10]. This is associated with better retention of flavor, color and bioactive compounds during the drying process, in comparison to conventional methods [11,12].

Passion fruit powder can be used as a flavoring ingredient in food products such as ice cream and yogurt [13]. Yogurt is a popular dairy product typically produced by the fermentation activity of *Lactobacillus delbrueckii* and *Streptococcus thermophilus* [14]. Depending on the raw materials used, yogurt differs in fat and total solids content, in form (stirred, set-style, frozen, concentrated) and may be produced with or without additives, probiotic microflora and in different flavors [15]. It is a source of essential macro- and micronutrients and contributes to the daily energy intake [16]. Addition of fruit-based additives to yoghurt enhances sensory appeal, nutritional value and could introduce health boosting phytochemicals [17,18,19]. Fruits like passion fruit are rich in dietary fiber, minerals as well as many bioactive compounds, such as antioxidants, like carotenoids, ascorbic acid, tocopherols and phenolics [20]. Their increased consumption is, therefore, an effective strategy to increase antioxidants intake and may help to prevent chronic diseases, especially cancer and cardiovascular disease [21]. Addition of fruits and fruit based additives to yogurt may also cause change in its consistency and other rheological properties [22]. This study assessed the effect of adding passion fruit powder produced using RWD to the properties of yogurt.

2. MATERIALS AND METHODS

2.1 Preparation of Passion Fruit Powder

Passion fruits (purple variety) were procured from Kalerwe market, Kampala. The fruits were washed under running water, until the water stayed clear, then cut into halves. The mesocarps were scooped with a spoon and then the pulp was extracted manually with a sieve. The passion fruit pulp was mixed with carboxy-methyl cellulose (carrier agent) that was procured from Smakk International (U) Limited, Kampala in a ratio of 93:7(w/w) in a plastic bucket using a wooden ladle. This ratio was based on preliminary trails. The mixture (1000 g) was then dried at 82.9°C for 60 min using a laboratory RW drier developed by Makerere University (Utility Model reference number UG/U/2020/000012) to obtain 150 g of the dried sample. The dry passion fruit samples were removed from the drying surface and ground into powder using a laboratory mill (Musa body Machinery (U) LTD Kampala Model SY-1200). The powder obtained was then used in the flavoring of plain yogurt.

2.2 Determination of Chemical Composition of Passion Fruit Powder

Prior to using passion fruit powder in flavoring yogurt, it was analyzed for its phenolic content, total antioxidant activity, vitamin C and beta carotene content using methods outlined in 2.4.4, 2.4.5, 2.4.6 and 2.4.7 respectively.

2.3 Preparation of Passion Fruit Powder Flavored Yogurt

Plain and vanilla flavored commercial yogurt were purchased from Makerere University Food Technology Incubation Center and taken to the nutrition laboratory at Makerere University for flavoring and for comparison to passion fruit flavored yogurt. To make the passion fruit flavored yogurt, a small portion (100 mL) of plain yogurt was poured in a one litre container followed by addition of pre-weighed 2 g of passion fruit powder. The mixture was stirred gently using a ladle to obtain a uniform mixture void of lumps. The remaining portion of yogurt was then added up to a one litre mark and then the final mixing was done. The passion fruit flavored yogurt was then poured in a clean container and stored in a refrigerator at 4^{o}C for further determinations. Commercial plain and vanilla flavored yogurt to be compared with passion fruit flavored yogurt were stored under similar conditions.

2.4 Determination of Physico-chemical Properties of the Different Yogurt Samples

2.4.1 Determination of total titratable acidity and pH

Total titratable acidity and pH of yogurt were determined as described by Malik, Kempanna, & Paul [23]. pH was measured using a pH meter (Hanna instruments HI 2215 pH/ORP Meter Woonsocket RI USA). Titratable acidity was determined as lactic acid percentage by titrating with 0.1 N sodium hydroxide solution, using phenolphthalein as an indicator.

2.4.2 Determination of viscosity

Viscosity of different yogurt samples was determined using a rheometer (Brookfield DVIII Ultra Engineering Laboratories, Stoughton, MA, USA) as described by Maria et al. [24].

2.4.3 Determination of syneresis

Syneresis of the different yogurt samples was determined according to the method described by Sigdel, Ojha, & Karki, [25]. Approximately 15 g of yogurt gel was weighed, drained on muslin cloth for 30 min at room temperature (25°C) and the mass of the whey separating from the gel weighed. The syneresis was expressed as the percentage of the whey separated from gel over initial mass of the gel.

2.4.4 Determination of total phenolic content

2.4.4.1 Extraction of phenolic compounds and other antioxidants

The extraction method described by Makkar [26] was used with slight modifications. Briefly, about 2 g of yogurt was weighed into a falcon tube and mixed with 5 mL of extracting solution (80% methanol: 20% water solution, v/v). The falcon tube containing the mixture was suspended in an ultrasonicator (Bransonic series, M 2800- E; Branson Ultrasonics Co, Danbury, CT) containing water and subjected to ultrasonic treatment for 20 min at room temperature. The extract was immediately cooled in a refrigerator at 4°C for 10 min and then centrifuged at 1008 xg (Fischer scientific 225, Fisher Scientific Co. St. Louis, MO) for 10 min. The supernatant was collected into a separate falcon tube and stored at 4°C in a refrigerator. The residue was then further re-extracted as described above, to ensure efficient extraction. The two supernatants were pooled in a falcon tube and stored in a refrigerator at 4°C to be used in the determination of total phenolic content (TPC) and total antioxidant activity (TAA).

2.4.4.2 Quantification of total phenolic compounds

The TPC of the different yogurt samples was determined using the Folin- Ciocalteu colorimetric method [26] with some modifications. In brief, 100 µL of passion fruit powder flavored yogurt extract was pipetted into a test tube and covered with aluminum foil. Subsequently 0.25

mL of Folin–Ciocalteu reagent (0.2N) was added, left to stand for 5 min and then 1.25 mL of sodium carbonate (7.5% w/v) added. The mixture in the test tube was homogenized using a vortex and kept in dark at room temperature for 90 min to allow for color development. Absorbance was measured at 765 nm (Genesys 10- UV spectrophotometer, Thermo Electron Corporation) against 80% methanol as the blank. The total phenolic content was determined using the standard gallic acid calibration curve with varying concentrations (0.02– 0.125) mg/mL). The total phenolic content was expressed as mg GAE/100 g of the yogurt.

2.4.5 Determination of total antioxidant activity

The 1, 1-diphenyl-2-picrylhydrazyl (DPPH) method [27], which measures the free-radical scavenging capacity was used to measure TAA. To 50 µL of the yogurt extract, 2.9 mL of freshly prepared 80% methanol solution of 100 µM DPPH was added. The mixture was vortexed and allowed to stand in the dark at room temperature for 30 min. Absorbance of the resulting mixture was measured at 515 nm, using Genesys 10-UV spectrophotometer (Thermo Electron Corporation) against a blank (80% methanol). The free-radical scavenging activity of the pulp was calculated as follows.

$$\text{Scavenging activity (\%)} = \left[1 - \left(\frac{\text{Absorbance of sample}}{\text{Absorbance of control}}\right)\right] X100 \quad (1)$$

The antioxidant content was determined using a standard curve of ascorbic acid (0.1–8 µg/mL). The results were expressed as milligram vitamin C equivalents per 100 g of yogurt (mg VCE/100 g).

2.4.6 Determination of vitamin C content

Determination of vitamin C was done according to the method of Kumar et al. [28] with some modifications. About 1 g of passion yogurt was weighed, extracted using an extracting solvent prepared by mixing 160 mL of glacial acetic acid and 37 mL of orthophosphoric acid and the mixture made to 2 L using distilled water. The extract was then transferred into a 50 mL volumetric flask. Two, 5 mL aliquots of this solution were pipetted into two conical flasks. Each of the aliquots was titrated with indophenol solution until a faint but distinct rose-pink color persisted for at least 5 seconds. Vitamin C content in the sample was estimated as mg ascorbic acid per 100 g of yogurt using equation 2.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre value of DCPIP} \times \text{DCPIP equiv} \times \text{Total volume of extract} \times 100}{\text{Sample weight} \times \text{Volume of extract pipeted for titration}} \quad (2)$$

2.4.7 Determination of total carotenoids

Total carotenoids in the different yogurt samples were determined according to the method of Rodriguez-Amaya & Kimura [29]. Briefly, 2 g of passion fruit powder flavored yogurt was extracted by mixing with 50 mL cold acetone in the dark and transferred into a separating funnel containing 30 mL of petroleum ether. The acetone was removed through the slow addition of 250 mL double distilled water with the separating funnel at an angle of 45^o to prevent the formation of emulsions. The aqueous phase was discarded and this procedure was repeated four times until there was no residual acetone. The extract was then transferred through a funnel into a 50 mL volumetric flask containing glass wool with 15 g of anhydrous sodium sulfate. The final volume was adjusted with petroleum ether. Absorbance was measured at 450 nm (Genesys 10-UV spectrophotometer, Thermo Electron Corporation, Madison, WI) against petroleum ether as a blank. The total carotenoid content was calculated using the following formula:

$$\text{Carotenoid s content } (\mu g/g) = \frac{A \times V(ml) \times 10^4}{A_{1cm}^{1\%} \times p(g)} \quad (3)$$

Where A = Absorbance; V = Total extract volume; p = sample weight; $A_{1cm}^{1\%}$ = 2592 (β-carotene Extinction Coefficient in petroleum ether).

$$\text{Then } \beta\text{ - carotene } (\mu g \text{ RAE}) = \frac{\text{Carotenoid content}}{12} \quad (4)$$

2.5 Sensory Evaluation of the Different Yogurt Samples

Sensory acceptance based on a 9 point hedonic scale [7] was conducted on yogurts flavored with different levels of RW dried passion fruit powder, in order to determine the most acceptable powder incorporation level. The range of RW dried passion fruit powder incorporation levels (Table 3) was based on results from preliminary trials (results not presented). Passion fruit flavored yogurt, vanilla flavored yogurt and plain yogurt stored 4°C were assessed for sensory acceptance at day 0, 7 and 14, in order to determine changes in sensory properties during storage over a storage period of 14 days. In all cases, a panel consisting 30 untrained panellists was used. Yogurt (at 5 ± 1°C) was served in plastic disposable cups labelled with a three-digit random number. The panellists scored the samples for color, flavor, taste, mouth feel, consistency, and overall acceptability, on a nine point hedonic scale (like extremely = 9 to dislike extremely = 1).

2.6 Statistical Analysis

Statistical analyses were performed using XLSTAT software version 2019. Results for sensory acceptability of yogurt samples were subjected to one-way ANOVA while those for physicochemical properties and phytochemicals content of the different yogurts during storage were analysed using two-way ANOVA. In both cases, Fischer's least significance difference test was used to separate means. All results were considered to be significant when the p value was <0.05.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Passion Fruit Powder

The composition of the passion fruit powder was moisture (10.9±0.6%), vitamin C (57.9±0.9 mg/100g), total antioxidant activity (367.0±1.0 mg/100g ascorbic acid equiv), beta carotene content (7.9±1.2 µgRAE/100g) and total phenolics (351.9±0.4 mg/100g Galic acid equiv).

3.2 Sensory Acceptability of Yogurt Samples with Different Levels of Passion Fruit Powder, Plain and Vanilla Flavored Commercial Yogurt

The overall acceptability yogurt incorporated with 2% of passion fruit powder was significantly higher than yogurts with other levels of passion fruit powder (Table 1). This was compared with controls (plain and vanilla-flavored commercial yogurt) and used in the subsequent experiments. In comparison with vanilla flavored commercial yogurt and yogurt with 2% of passion fruit powder, plain yogurt had a significantly (p<0.05) lower score for flavor, color, taste, and overall acceptability. There, however, was no significant difference (p<0.05) between passion fruit powder flavored yogurt and the vanilla flavored commercial yogurt for color, flavor, taste mouth feel and overall acceptability. This indicates that passion fruit powder has the potential of being used as a flavoring agent in yogurts and can compete with artificial flavors in most commercial yogurts. The consistency of passion fruit flavored yogurt was significantly higher (p<0.05) than that for the other yogurt types. This is in agreement with [24] who reported that consistency and viscosity of yogurt enriched with both 2% and 4% passion fruit peel powder presented higher scores compared with yogurt without passion peel powder and attributed this fact to the higher fiber contents of such samples, which may be responsible for the thick and viscous texture.

3.3 Physicochemical Parameters of Different Yogurts during Storage

3.3.1 Changes in pH and titratable acidity of the different yogurts during storage

The flavoring of yogurt with passion fruit powder and storage time all significantly (p<0.05) reduced pH and increased the titratable acidity of yogurt (Table 2). During storage, the pH reduced and titratable acidity increased for all the yogurts irrespective of the flavoring used. The pH of passion fruit powder flavored yogurt was significantly lower (p<0.05) than that of the other yogurts throughout the 14 days of storage and this is explained by the low pH of the passion fruit pulp powder (3.12). There was a reduction in pH and an increase in titratable acidity for all yogurt types throughout the 14 day storage period for all yogurt types with pH values and titratable acidity ranging from 4.67 to 3.77 and 1.21% to 2.89%, respectively. The increase in acidity was expected due to the continued activity of the microbes (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. Bulgaricus) in the yogurt [30,31,24].

3.3.2 Changes in viscosity of the different yogurts during storage

The flavoring of yogurt with passion fruit powder significantly (p<0.05) increased the viscosity of yogurt. The apparent viscosity of the yogurts ranged from 413.76 cP to 525.20 cP (Table 2). Viscosity of all the yogurt types increased significantly (p<0.05) from day zero to the 7th day and 14th day of storage irrespective of the flavoring used. There was no interaction between the type of flavoring used and storage time. During the storage time, the increased viscosity could be regarded as recovery of structure or re-bodying [32]. There was a significant difference (p<0.05) between

Table 1. Sensory acceptability of yogurt samples with different levels of passion fruit powder, plain and vanilla flavored commercial yogurt

	Sensory attribute					
Incorporation level (%)	**Color**	**Flavor**	**Taste**	**Mouth feel**	**Consistency**	**Overall acceptability**
0.5	7.2^a±0.92	6.2^c±0.92	7.0^a±2.02	7.6^a±2.41	6.4^b±0.91	$6.8.0^b$±2.36
1	7.6^a±0.76	7.1^b±0.75	7.0^a±1.78	7.6^a±2.01	6.4^b±1.23	6.6^b±1.55
2	7.7^a±2.24	8.0^a±2.01	7.6^a±0.35	7.6^a±0.92	7.4^a±1.26	7.7^a±1.24
3	7.8^a±0.51	8.0^a±1.52	7.4^a±1.55	6.7^b±2.11	7.4^a±1.54	6.8^b±2.45
4	7.7^a±0.64	8.2^a±1.07	7.0^a±2.21	6.6^b±0.43	6.4^b±2.68	6.6^b±1.97
5	7.9^a±0.99	8.0^a±1.69	6.0^b±1.99	6.5^b±1.68	6.4^b±2.82	6.0^{bc}±0.24
Plain yogurt	6.2^b±1.07	5.8^c±1.17	5.6^b±1.24	7.6^a±0.08	6.0^b±0.62	6.4^b±0.42
Vanilla-flavored commercial yogurt	7.8^a±1.11	8.0^a±1.29	7.8^a±0.07	7.5^a±0.07	6.4^b±2.01	7.8^a±0.79

Values are mean scores of 30 untrained panelists ± standard deviations. Means in the same column with different superscripts are significantly different (P < 0.05)

the apparent viscosity of passion fruit powder flavored yogurt and the other yogurts on day zero and throughout the storage period. The available carbohydrates, fiber and pectic substances in the passion fruit powder could have improved the structure of the curd network of stirred yogurt and increased the viscosity [33,34]. Fiber and carboxy-methyl cellulose in the passion fruit powder formed a three-dimensional network capable of complexing the milk components while absorbing maximum water of the medium resulting in an increase in viscosity [31].

3.3.3 Changes in syneresis of the different yogurts during storage

Syneresis is defined as spontaneous water release from a gel caused by contraction [35] and is a common problem in fermented milk products like yogurt [36]. The syneresis of yogurts ranged from 25.6% to 32.2% (Table 2). There was a significant difference between synerisis of passion fruit powder flavored yogurt and the other types of yogurts with passion fruit flavored yogurt having the lowest syneresis at all periods of storage as well as a non-significant change in syneresis of passion fruit powder flavored yogurt in the first week of storage. This may be due to the higher level of the available carbohydrates, fiber and pectic substances in passion fruit flavored yoghurt, as these components exhibit water binding force in acidic medium [34]. Other researchers [18] also observed a reduction in syneresis in pumpkin yogurt during storage. There was also an increase in syneresis with storage irrespective of the whether the yogurt was flavored with passion fruit powder or not. This could be due to the increase in acidity during the storage [35]. During storage, pH values decreased while the syneresis values increased (Table 2). Similar observations were reported in earlier studies [36,37], and has been attributed to milk acidification, which leads to decrease of the charges on caseins, which results in weakening of the electrostatic forces holding micelles together and weaker steric stabilization. This decreases the attractive force between micelles, which become ‘adhesive’ or ‘sticky’ and forms a weak particle gel with serum separation [38].

3.3.4 Changes in ascorbic acid and carotenoid content of the different yogurts during storage

The vitamin C content of the yogurts ranged from 0.69 mg/100g to 1.91 mg/100g with passion fruit powder flavored yogurt having a significantly higher ($p<0.05$) vitamin C content than other yogurts (Table 3). There was no change in the vitamin C content of all yogurts during storage. The higher vitamin C content of passion fruit flavored powder is attributed to the fact that passion fruit is a good source of vitamin C [9]. Ścibisz, Ziarno, & Mitek [39] also reported higher L-ascorbic acid content for yogurt enriched with straw berry and blue berry fruits as compared to plain yogurt and observed a reduction in L-ascorbic acid content with storage.

The carotenoid content of yogurts ranged from 0.55 µgRAE to 1.07 µgRAE. The total carotenoid content of passion fruit flavored yogurt was significantly higher ($p<0.05$) than that for the other yogurts. This could attributed to the fact

Table 2. Physico-chemical parameters of different yogurts after 0, 7 and 14 days at 4°C ± 1°C

Item	Treatment	Storage (days)		
		0	7	14
pH	Plain	4.69^{aA}±0.89	4.40^{aB}±0.09	4.19^{aC}±0.67
	Commercial	4.67^{aA}±0.71	4.34^{aB}±0.16	4.06^{aC}±0.24
	Passion fruit flavored	4.41^{bA}±0.63	4.10^{bB}±0.41	3.77^{bC}±0.06
Titratable acidity (%)	Plain	1.21^{bB}±0.17	1.56^{bAB}±0.27	1.79^{bA}±0.03
	Commercial	1.19^{bB}±0.21	1.61^{bAB}±0.09	1.76^{bA}±0.17
	Passion fruit flavored	2.06^{aB}±0.33	2.58^{aAB}±0.76	2.89^{aA}±0.51
Apparent viscosity (cP)	Plain	413.76^{bC}±0.11	460.63^{bB}±0.16	516.41^{bA}±0.31
	Commercial	414.08^{bC}±0.03	462.01^{bB}±0.23	517.00^{bA}±0.09
	Passion fruit flavored	419.23^{aC}±0.13	471.07^{aB}±0.19	525.20^{aA}±0.24
Syneresis (%)	Plain	27.9^{aB}±1.13	28.6^{aB}±1.81	31.9^{aA}±0.86
	Commercial	28.2^{aB}±0.96	28.9^{aB}±0.99	32.2^{aA}±0.59
	Passion fruit flavored	25.6^{bB}±1.72	26.7^{bA}±1.53	26.9^{bA}±1.11

Means followed by different capital letters within a row show a significant difference between storage times (p<0.05). Means followed by different lower case letters within columns show difference between the different yogurts

that passion fruit powder contains carotenoids [4]. Total carotenoid content of all yogurts reduced significantly (p<0.05) during storage (Table 3). This is in agreement with [18] who noted reduction of total carotenoids in stirred pumpkin yogurt during storage. The reduction in carotenoid content of yogurts during storage could have resulted from oxidation and discoloration of carotenoids by lipid radicals resulting from auto-oxidation of linoleic acid during storage [40].

3.3.5 Changes in phenolic content of the different yogurts during storage

The phenolic content of the yogurts ranged from 0.50 mg /100 g GAE to 8.01 mg/100 g GAE (Table 3). It was observed that plain yogurt had some phenolic compounds. The presence of phenolic compounds in plain milk and dairy products may be a consequence of a multiple of circumstances including: pasture-derived and amino acid catabolism [16]. Passion fruit flavored yogurt had significantly (p<0.05) higher phenolic content than other yogurts (Table 3). This is in agreement with [41] who reported increase in phenolic content of yogurt enriched with passion fruit juice. There was a significant (p<0.05) reduction in the phenolics content of all yogurt types during storage. The phenolic compounds from fruit preparation could have interacted with caseins or whey proteins causing the formation of soluble or insoluble complexes, which are responsible for the decrease of phenolics content [39]. Álvarez et al. [42] also observed that the phenolics content of beans decreased after 6 days of fermentation.

3.3.6 Anti-oxidant activity of the different yogurts and the effect of storage period

Passion fruit flavored yogurt had significantly (p<0.05) higher antioxidant activity than the other yogurts. This was expected since passion fruits are a rich source of phytochemicals [43]. Nguyen & Hwang [44] also reported increase in DPPH radical scavenging activity of yogurt enriched with black chokeberries. Total antioxidant activity of passion fruit flavored yogurt increased significantly (p<0.05) during storage (Table 3). The increase in antioxidant activity with storage may be attributed to microbial metabolic activity releasing some bounded bioactive materials [18]. Rahmawati and Suntornsuk [45] reported increased antioxidant activity in cow, goat, and buffalo yogurt during storage and attributed this to the release of bioactive (antioxidant) peptides occurring as a result of protein digestion by bacterial fermentation. Peptides generated in milk digestion may act as electron donors reacting with free radicals to form more stable products [46]. Several studies have also reported increase in antioxidant activity as a result of fermentation. Hur et al. [47] reported increase in antioxidant activity in fermented plant based-foods due to increased release of flavonoids during fermentation. Fermentation induces synthesis of various bioactive compounds as a result of induced structural breakdown of the cell walls [48]. Fermentation is also associated with modification of composition of bioactive compounds by LAB [49,50,51].

3.4 Sensory Evaluation of Different Yogurts during Storage

The sensory acceptability of yogurt on the first day of storage is presented in Fig. 1. For all yogurt types, there was no significant change ($p<0.05$) in any of the sensory parameters (flavor, color, mouth feel, consistency, taste and overall acceptability) over the storage period of 14 days, indicating that storage at 4°C was sufficient to preserve the sensory attributes of the yogurts for 2 weeks. Since 2 weeks is the recommended period given for refrigerated storage of yogurt [52], these results show that the storage stability of passion fruit flavored yoghurt is within the acceptable range.

Table 3. Phyto-chemical composition of different yogurts after 0, 7 and 14 days at 4°C ± 1°C

Item	Treatment	Storage (days)		
		0	7	14
Vitamin C (mg/100g)	Plain	$0.73^{bA}\pm0.06$	$0.70^{bA}\pm0.11$	$0.68^{bA}\pm0.23$
	Commercial	$0.69^{bA}\pm0.10$	$0.60^{bA}\pm0.09$	$0.58^{bA}\pm0.04$
	Passion fruit flavored	$1.91^{aA}\pm0.09$	$1.89^{aA}\pm0.13$	$1.87^{aA}\pm0.41$
Total carotenoids (µgRAE)	Plain	$0.72^{bA}\pm0.03$	$0.57^{bB}\pm0.15$	$0.46^{bC}\pm0.21$
	Commercial	$0.69^{bA}\pm0.35$	$0.56^{bB}\pm0.33$	$0.44^{bC}\pm0.09$
	Passion fruit flavored	$1.87^{aA}\pm0.08$	$1.44^{aB}\pm0.09$	$1.12^{aC}\pm0.10$
Total phenolic content (mg/100g GAE)	Plain	$0.95^{bA}\pm0.02$	$0.76^{bB}\pm0.04$	$0.50^{bC}\pm0.03$
	Commercial	$0.93^{bA}\pm0.05$	$0.71^{bB}\pm0.13$	$0.51^{bC}\pm0.06$
	Passion fruit flavored	$8.01^{aA}\pm0.11$	$7.01^{aB}\pm0.10$	$5.35^{aC}\pm0.09$
Total antioxidant activity (mg/100 g VCE)	Plain	$0.25^{bA}\pm0.03$	$0.27^{bA}\pm0.07$	$0.27^{bA}\pm0.10$
	Commercial	$0.21^{bA}\pm0.05$	$0.23^{bA}\pm0.13$	$0.24^{bA}\pm0.09$
	Passion fruit flavored	$7.64^{aC}\pm0.79$	$8.79^{aB}\pm0.18$	$9.96^{aA}\pm0.37$

Means followed by different capital letters within a row show a significant difference between storage times ($p<0.05$). Means followed by different lower case letters within columns show difference between the different yogurts ($p<0.05$)

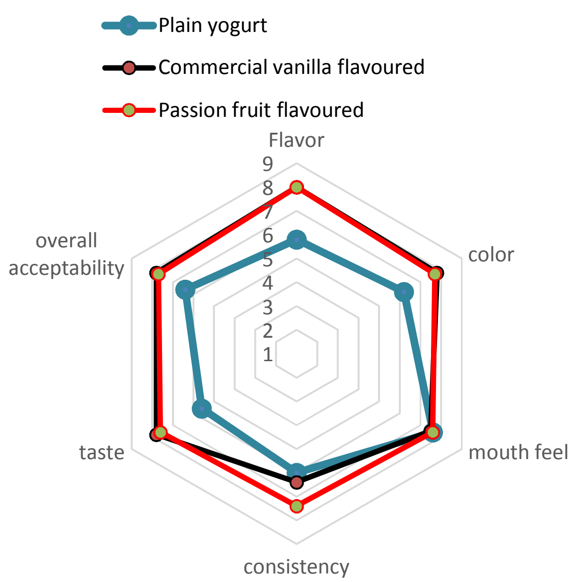

Fig. 1. Sensory evaluation of different yogurts on the first day of storage

4. CONCLUSION

This study demonstrated that refractance window drying is an efficient method for drying passion fruit pulp into good quality powder. The study further demonstrated that RW dried passion fruit powder is suitable for use as a flavoring for yogurt. Its addition to yogurt resulted in higher levels of vitamin C, beta carotenoid, total phenolics content and total antioxidant activity, in comparison to plain yoghurt and commercial vanilla flavored yoghurt. Passion fruit flavored yoghurt was more acceptable than plain yoghurt and as acceptable as commercial vanilla flavored yoghurt. Addition of passion fruit powder did not affect storage stability of yogurt and the flavored yoghurt remained acceptable after 2 weeks storage at refrigeration temperature. These results provide processors with evidence that passion flavored yogurt is acceptable and compares well with other commercial yogurts. This will prompt some processors to commercialize passion flavored yogurt. This will provide consumers with more nutritious options thereby improving nutrition of consumers.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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