EVALUATION OF THE STIRRED YOGHURT QUALITY FORTIFIED WITH PAPAYA FRUIT PULP

By

Azza S. Abdel-Ghany

Food Science Department (Rural Home Economics), Faculty of Agriculture, Zagazig University, Zagazig, Egypt.

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Abstract:

Stirred yoghurt enriched with papaya fruit pulp at 5%, 10%, and 15% was prepared and analyzed alongside control samples. Both the fortified and control yoghurts were evaluated for chemical composition, antioxidant activity, physical properties, sensory attributes, and microbiological characteristics at the time of preparation and after 5, 10, and 15 days of storage at 5°C. The results revealed that total solids, ash, and fiber content increased in the papaya-enriched yoghurt compared to the control, while protein and fat content decreased. Total phenolic content and antioxidant activity significantly improved with higher papaya pulp levels. The inclusion of 10% and 15% papaya pulp notably reduced the yoghurt's pH, whereas titratable acidity increased. Syneresis was highest in the 5% papaya pulp sample, while viscosity was greatest in the 15% pulp sample. Papaya pulp also influenced the yoghurt's color, decreasing lightness while significantly increasing redness and yellowness as pulp levels rose. Sensory evaluation confirmed that all fortified yoghurts were well-accepted, with scores of 96.40% for 5% pulp, 95.30% for 10% pulp, and 93.00% for 15% pulp. The highest S. thermophilus and L. bulgaricus counts were recorded on the 5th day of storage across all treatments. Overall, the study demonstrated that fortifying stirred yoghurt with papaya pulp significantly enhanced its physicochemical properties and antioxidant activity.

Key words: Stirred yoghurt, Papaya fruit pulp, Antioxidant activity, Rheological properties.

* Food Science Department (Rural Home Economics), Faculty of Agriculture, Zagazig University, Egypt.
Authors e-mail: az_dr_eg@yahoo.com

INTRODUCTION

Yoghurt is a staple fermented dairy product consumed worldwide for its nutritional value, probiotic benefits, and versatility. Its popularity spans cultures and demographics due to its creamy texture, tangy flavor, and health-promoting properties, including improved gut health, immune modulation, and enhanced lactose digestion **(Abdi-Moghadam *et al*., 2023)**. Within the past few years, there has been a growing consumer appeal to functional foods that deliver health perks exceeding essential nutrition. This trend has driven research and development in the dairy sector toward incorporating natural ingredients like fruits, which can significantly enhance the health benefits and sensory appeal of yoghurt **(Granato *et al*., 2010, and Baker *et al*., 2022)**.

Adding fruits to yoghurt offers a dual advantage: improving its nutritional profile while enhancing its sensory qualities, such as flavor, color, and texture. Fruits are abundant in essential nutrients as dietary fiber, vitamins, minerals, and bioactive compounds like carotenoids and polyphenols, which are recognized for their antioxidant effects **(Ranadheera *et al*., 2017, and Kamber & Harmankaya, 2019)**. These compounds are crucial in counteracting free radicals, thereby mitigating oxidative stress and lowering the likelihood of chronic conditions like cardiovascular diseases, diabetes, and certain cancers **(Muscolo *et al*., 2024)**. Among various fruits, papaya (*Carica papaya*) stands out caused of its rich content of carotenoids and lycopene, as well as its high levels of vitamin C, flavonoids, and digestive enzymes like papain **(Martial-Didier *et al*., 2017)**.

Papaya is a tropical fruit containing a distinctive combination of health-enhancing properties. It is widely recognized for its antioxidant, antimicrobial, and anti-inflammatory effects, which can contribute to improving the quality and functionality of fortified foods **(Koul *et al*., 2022)**. It's a natural sweetness and vibrant orange-yellow color makes it a suitable candidate for fortifying yoghurt, enhancing not only the nutritional profile but also the visual and sensory appeal of the product. However, the integration of papaya pulp into yoghurt raises technical challenges, including its impact on the product's physicochemical properties, microbial stability, and consumer acceptability **(Teshome *et al*., 2017, and Manzoor *et al*., 2019).**

The physicochemical properties of yoghurt, such as pH, titratable acidity, viscosity, and syneresis, are critical determinants of product quality and consumer satisfaction. Fortification with fruit pulp can influence these attributes by altering the protein matrix and interactions within the yoghurt. For example, the natural sugars and organic acids in papaya pulp can interact with the fermentation process, leading to changes in acidity, texture, and overall stability **(Tamime and Robinson, 1999)**. Moreover, the bioactive compounds found in papaya pulp, including phenolics and carotenoids, may boost the antioxidant activity of yoghurt, transforming it into a functional food with additional health benefits **(Jeon *et al*., 2022).**

Sensory evaluation is a vital aspect of functional food development. While the augmentation of papaya pulp can improve flavor and color, the concentration of pulp must be optimized to balance these enhancements with consumer preferences (**Wajs *et al*., 2023)**. Excessive fruit pulp can lead to textural changes, increased syneresis, and reduced acceptability. Therefore, understanding the optimal concentration of papaya pulp and its influence on the sensory profile of yoghurt is essential for product success **(Roy *et al*., 2015, and Munteanu-Ichim *et al*., 2024).**

The purpose of this study was to investigate the potential impact of papaya pulp as a functional ingredient on the physicochemical, antioxidant, sensory, and microbiological properties of stirred yoghurt, during a 15-day storage period at 5°C. The study seeks to provide valuable insights into the development of functional, health-promoting dairy products that cater to the increasing demand for innovative and nutritionally enriched foods.

MATERIALS AND METHODS

Materials

Fresh cow's milk with 3% fat content was sourced from the Dairy Technology Unit, Food Science Department, Faculty of Agriculture, Zagazig University, Egypt. Fresh papaya was bought from the local market in Minya El-Qamh City. The starter strains were getting from the Microbiological Resources Center at the Faculty of Agriculture, Ain Shams University, Egypt.

Methods

Preparation of fruit pulp

Fresh mature papaya fruit were washed, peeled, and then aseptically cut using a knife. The pulp was manually separated from the arils and subsequently homogenized. The papaya pulp was pasteurized at 72°C for 15 sec and then cooled to 40±2°C. The pulp was stored in a sterilized glass bottle in the refrigerator at 5°C.

Preparation of yoghurt

Skim milk powder (2%) was added to fresh cow's milk containing 3% fat. The milk was exposed to 90°C for 15 min. and then lowered to 40± 3°C. It was then sectioned into four equal quantities. Each one was inoculated with 2% starter culture and incubated at 42°C ± 1°C until complete coagulation. The first quantity served as a control, and then the other three quantities were blended with pasteurized papaya pulp at concentrations of 5%, 10%, and 15% to produce flavored stirred yoghurt. Each mixture was blended using a stainless-steel blender for 1 minute to ensure uniformity. The all-synthesized yoghurt was relocated into plastic containers and stored for 15 days at 5°C to analyze it at fresh 5,10, and 15days intervals.

Sensory evaluation

The sensory evaluation of all yoghurt samples was based on the following criteria: flavor (45 points), body and texture (30 points), appearance (15 points), acidity (10 points), and overall acceptability (out of 100 points). The evaluations were conducted by 10 panelists, all staff members of the Food Science Department, Faculty of Agriculture, Zagazig University, following the methodology described by **Kamel *et al*. (2021).**

Methods of analysis

Chemical analysis

The moisture, total solids, fat, total protein, ash, carbohydrates, crude fiber contents, and titratable acidity of milk, papaya pulp, and yoghurt samples were analyzed following the methods outlined by **AOAC (2007).** The pH of yoghurt samples was monitored using a HANNA Instruments pH meter (Portugal).

Determination of total phenolic content and Radical scavenging activity (Scavenging DPPH)

The content of total phenolic to papaya pulp extract was determined by the **Syafitri *et al*. (2024)** method. The electron-donating ability of the extracts was assessed by measuring the bleaching of the purple-colored DPPH solution, as outlined by **Krasteva *et al*. (2023)**.

Rheological measurements

Curd syneresis volume in yoghurt samples was measured after 2 h at room temperature **(Farouq and Haque,1992).** The viscosity of stirred yoghurt samples was measured using a rotational viscometer **Aryana (2003)**, results are represented by centipoise (CPS). The three-color coordinates (lightness (*L**), redness (*a**), and yellowness (*b**) of all stirred yoghurt samples were gauged by a Hunter colorimeter (Color Flex EZ, USA) **(Pathare *et al*., 2013)**.

Microbiological examination

All yoghurt samples were counted for total bacterial, *Lactobacillius delbrueckii* subsp. *bulgaricus*, *S. thermophiles,* total coliforms, molds and yeasts content according to **American Public Health Association (1992a)**, **Dave and Shah (1996)**, **(Terzaghi and Sandine, 1975)**, **American Public Health Association (1992b) and Difco (1984),** respectively**.**

Statistical analysis

The obtained data were statistically processed using the Statistix 10 software **(Statistix 10, 2023)**. The results are supplied as mean ± SD.

Statistical variations between treatments and storage periods were determined using the least significant difference test.

RESULTS AND DISCUSSION

Chemical composition of cow milk and papaya fruit pulp

The chemical structure of cow milk and papaya pulp which were used to prepare the stirred yoghurt are shown in Table (1). The moisture, total solids, protein, fat, ash, and carbohydrates content of cow milk was 88.83, 11.17, 3.33, 3.02, 0.74%, and 4.08% respectively. Too, the papaya pulp contained 81.16% moisture, 18.84% total solids, 1.36% protein, 0.41% fat,1.11% ash, 15.96% carbohydrates, and 1.71% crude fiber. The content of total solids and fat for papaya pulp in this study was higher than that determined by **Ahmed and Zubeir (2021)** (12.01 and 0.38%, respectively), while the content of protein, ash, and crude fiber were lower (5.1, 1.97 and 2.66%, respectively). Also, **Ebrahim *et al*. (2024)** noted that the protein, fat ash, and fiber contents in papaya pulp were 0.79, 0.46, 0.43, and 1.67%, respectively.

The same table shows the total phenolic content and radical scavenging activity of ethanolic extracts from papaya pulp were 178.82 mg/100g and 84.15%, respectively. The content of total phenolic in this study was lower than that established by **Wani and Uppaluri (2022)**, while the radical scavenging activity was higher than the 77.48% reported by **Ebrahim *et al*. (2024)**. These differences due to influenced by some factors such as variety of sources, growing conditions, climate, and extraction methods.

Chemical composition of stirred yoghurt

The chemical composition of yoghurt samples showed distinct variations with different concentrations of papaya pulp (5%, 10%, and 15%) across storage periods. These variations indicate that adding papaya pulp affected the composition of the yoghurt, with the concentration of papaya pulp and storage duration playing key roles in altering the nutritional profile of the product.

Table (1): Chemical composition of cow milk and papaya fruit pulp

Chemical composition	Cow milk	Papaya pulp
Moisture (%)	88.83± 1.35	81.16± 1.61
Total solids (%)	11.17± 1.35	18.84± 1.61
Total protein (%)	3.33± 0.14	1.36± 0.17
Fat (%)	3.02± 0.07	0.41± 0.03
Ash (%)	0.74± 0.12	1.11± 0.14
Carbohydrates (%)	4.08± 1.51	15.96± 1.28
Crude fiber (%)	-	1.71± 0.04
Total phenolic compounds (mg/100g)	-	178.82± 53.03
Radical scavenging activity (%)	-	84.15± 1.09

The data in Table (2) indicated that the control stirred yoghurt contained a significantly lower total solid than that in the yoghurt samples with varying levels of papaya pulp. The total solids content of yoghurt was augmented as the percentage of papaya pulp and storage time increased. This can be because of the higher total solids in the papaya pulp, thus the water-binding capacity and the additional solids from the fruit pulp enhance the total solid content of yoghurt. Similar trends were observed in previous studies **(Fadela *et al.*, 2009, and Barakat & Hassan, 2017)**. On the other hand, these results contrast with those of **Hossain *et al*. (2012)**, who concluded that the total solids content declined as the percentage of fruit increased, owing to the lower fat and protein content in the fruit.

Adding papaya pulp resulted in a significant decrease in the content of protein compared to the control. The lower protein content in yoghurt with papaya pulp could be due to the dilution effect of added fruit pulp, which has a lower protein concentration compared to milk. **(Ghalem and Zouaoui, 2013)**. These findings align with those of **Teshome *et al*. (2017)**, who observed that incorporating mango and papaya juices into yoghurt leads to reduced protein content. The protein content of both the control and fortified yoghurt significantly increased as the storage period progressed. This can be attributed to the fermentation process, where microbial activity likely enhanced protein breakdown and synthesis, consistent with the conclusions of **Barakat and Hassan (2017)**.

Fat content in stirred yoghurt exhibited a decreasing trend with the increase in papaya pulp percentage compared with the control, this is due to a reduction of fat content in papaya pulp. These results were similar to those obtained by **Farahat & El-Batawy (2013), Teshome *et al.* (2017), and Othman *et al.* (2019),** who reported that adding papaya juice and puree to yoghurt resulted in the fat content decline of yoghurt. During storage, the fat content of both the control and fruit yoghurt samples showed a noteworthy increase by the 15^{th} day of storage compared to the fresh samples. These results are harmonious with the results of **Barakat and Hassan (2017)**.

Ash content also increased with a rise ratio of papaya pulp and longer storage times. This suggests that the mineral content of papaya pulp contributed to an increase in the overall mineral profile of the yoghurt. These findings align with **Othman *et al.* (2019)**, who manifested that the ash content in yoghurt fortified with papaya puree increased as the proportion of papaya puree rose. At the same time, they contradict the results of **Debashis *et al.* (2015)**, who obviously a decline in ash content with a higher proportion of papaya pulp in yoghurt. During storage, the content of ash in the yoghurt samples elevated with advanced storage periods. This rise was significant at day 15 of storage compared with fresh samples. This may be due to the vaporization of some moisture through storage, and the total solids increased **(Barakat and Hassan, 2017).** These outcomes are regular with the ones mentioned by **Tefera *et al.* (2019).**

The crud fiber content of stirred yoghurt was elevated by an increment in the papaya pulp ratio. Fruit and vegetable fibers are incorporated into food products to enhance physiological functionalities such as viscosity, hydration capacity, oil-binding ability, and antioxidant activity. Moreover, the incorporation of fruit pulp into yoghurt enhances its fiber content, making it a healthier option with potential digestive benefits. **(Sendra *et al.*, 2010).** Also, there was no impact of storage at 5°C for 15 days on the crud fiber content of all stirred yoghurt samples.

Table (2): Chemical composition (%) of stirred yoghurt fortified with papaya fruit pulp during 15 days of storage at 5° C

Chemical composition (%)	Storage periods (day)	Control yoghurt	Yoghurt with papaya fruit pulp		
			5%	10%	15%
Total solids	Fresh	13.00± 0.09^{D,d}	14.04± 0.04^{C,d}	14.57± 0.03^{B,d}	15.58± 0.05^{A,d}
	5	13.83± 0.11^{D,c}	14.96± 0.06^{C,c}	15.43± 0.12^{B,c}	16.23± 0.01^{A,c}
	10	14.65± 0.13^{D,b}	15.72± 0.07^{C,b}	16.20± 0.03^{B,b}	17.17± 0.07^{A,b}
	15	15.31± 0.03^{D,a}	16.41± 0.05^{C,a}	17.07± 0.06^{B,a}	17.41± 0.06^{A,a}
Total protein	Fresh	3.79± 0.01^{A,d}	3.43± 0.04^{B,d}	3.33± 0.03^{C,d}	3.26± 0.04^{D,d}
	5	4.27± 0.03^{A,c}	3.85± 0.02^{B,c}	3.75± 0.04^{C,c}	3.57± 0.04^{D,c}
	10	5.09± 0.10^{A,b}	4.22± 0.11^{B,b}	4.15± 0.06^{B,b}	4.09± 0.01^{B,b}
	15	5.41± 0.05^{A,a}	4.95± 0.07^{B,a}	4.64± 0.07^{C,a}	4.53± 0.08^{C,a}
Fat	Fresh	3.09± 0.01^{A,b}	2.72± 0.08^{B,c}	2.65± 0.05^{B,b}	2.51± 0.01^{C,c}
	5	3.18± 0.07^{A,b}	2.87± 0.12^{B,bc}	2.67± 0.04^{C,b}	2.60± 0.10^{C,bc}
	10	3.21± 0.07^{A,b}	2.94± 0.08^{B,b}	2.72± 0.08^{C,b}	2.67± 0.06^{C,b}
	15	3.38± 0.10^{A,a}	3.17± 0.15^{B,a}	3.10± 0.12^{B,a}	2.82± 0.07^{C,a}
Ash	Fresh	0.73± 0.03^{C,c}	0.76± 0.01^{BC,b}	0.80± 0.05^{B,b}	0.86± 0.02^{A,b}
	5	0.75± 0.05^{B,bc}	0.78± 0.04^{B,b}	0.81± 0.06^{AB,b}	0.87± 0.01^{A,b}
	10	0.82± 0.04^{A,ab}	0.83± 0.05^{A,b}	0.85± 0.03^{A,ab}	0.88± 0.02^{A,ab}
	15	0.89± 0.05^{A,a}	0.91± 0.03^{A,a}	0.94± 0.07^{A,a}	0.96± 0.09^{A,a}
Carbohydrates	Fresh	5.39± 0.12^{D,b}	7.12± 0.14^{C,c}	7.79± 0.07^{B,c}	8.95± 0.02^{A,c}
	5	5.64± 0.10^{D,a}	7.47± 0.16^{C,b}	8.20± 0.10^{B,b}	9.19± 0,07^{A,b}
	10	5.54±0.05^{D,ab}	7.73± 0.14^{C,a}	8.49± 0.01^{B,a}	9.53± 0.06^{D,a}
	15	5.63± 0.10^{D,a}	7.38± 0.05^{C,b}	8.40±0.16^{B,a}	9.10± 0.06^{A,b}
Fiber	Fresh	0.00± 0.00^{D,a}	0.06± 0.001^{C,a}	0.11± 0.001^{B,a}	0.14± 0.001^{A,a}
	5	0.00± 0.00^{D,a}	0.06± 0.001^{C,a}	0.11± 0.002^{B,a}	0.14± 0.001^{A,a}
	10	0.00± 0.00^{D,a}	0.06± 0.001^{C,a}	0.11± 0.002^{B,a}	0.14± 0.002^{A,a}
	15	0.00± 0.00^{D,a}	0.07± 0.001^{C,a}	0.12± 0.001^{B,a}	0.15± 0.001^{A,a}

Means indicated using uppercase letters in the same row are significantly different ($P \leq 0.05$).
Means indicated using lowercase letters in the same column are significantly different ($P \leq 0.05$).

Total phenolic content of stirred yoghurt

The total phenolic content of the stirred yoghurt treatments is presented in Table (3). The fortification with papaya fruit pulp resulted in a substantial increment in the total phenolic content of the yoghurt compared to the control. Similar results were recorded by **El-Loly *et al*., (2024)**, who stated that the total phenolic compounds value of flavored processed cheese samples increased significantly by raising the papaya pulp percentages compared to control cheese. These results are also completely consistent with the conclusions of **El-Batawy *et al*. (2014) and Blassy *et al*. (2020),** who mentioned that enhancing yoghurt with fruit pulps led to the rise in the total phenolic compounds content, and the increase was consistent with the percentage of fruit pulp added. During storage, the total phenolic content of both the control and stirred yoghurt decreased as the storage period progressed. **Cheynier (2005)** concluded that the reduction in the total phenolic content during storage may be attributed to the conversion of phenolic compounds, which are unsteady and subject to many chemical and enzymatic reactions during storage**.**

Table (3): Total phenolic content of `stirred yoghurt during 15 days of storage at 5° C

Storage periods (day)	Control yoghurt	Yoghurt with papaya fruit pulp		
		5%	10%	15%
Fresh	65.36± 2.40^{D,a}	85.72± 5.13^{C,a}	118.47±10.41^{B,a}	166.43± 1.47^{A,a}
5	34.16± 2.03^{D,b}	44.80± 1.13^{C,b}	95.67± 1.29^{B,b}	102.70± 6.88^{A,b}
10	20.32± 3.03^{D,c}	32.42± 1.53^{C,c}	48.53± 4.80^{B,c}	63.94± 3.03^{A,c}
15	11.27± 1.66^{D,d}	20.86± 2.67^{C,d}	32.23± 4.11^{B,d}	53.90± 0.72^{A,d}

Means indicated using uppercase letters in the same row are significantly different ($P \leq 0.05$).
Means indicated using lowercase letters in the same column are significantly different ($P \leq 0.05$).

Radical scavenging activity of stirred yoghurt

The results in Fig. (1) indicate that the antioxidant activity increased significantly with the addition of papaya pulp. The highest antioxidant activity, recorded at 45.50%, was observed in stirred yoghurt fortified with 15% papaya pulp, while the lowermost activity, 24.54%, was found in the control yoghurt. This can be ascribed to the high levels of natural antioxidants and phenolic compounds present in papaya fruit **(Ebrahim *et al.*, 2024)**, which have gained significant attention for their probable to prevent or delay diseases linked to oxidative stress (**Nagarathna *et al.*, 2021**). Besides, papaya fruit contains carotenoids, which help neutralize free radicals generated during metabolism, reduce the oxidation of harmful cholesterol, and protect against cardiovascular diseases **(Matsuane *et al.*, 2023)**. It is also an outstanding source of vitamins, minerals, and fiber **(Chuwa and Kamal, 2022)**, indicating that processed yoghurt containing papaya fruit will be a good source to improve human health.

Furthermore, all yoghurt samples exposed a significant decrease in antioxidant activity as the storage period progressed, reaching its lowest values by the 15th day. This reduction can be ascribed to the decline in phenolic compounds and ascorbic acid concentrations over time **(Kulkarni and Aradhya, 2005).** Overall, the addition of fruit pulp was found to augment the total phenolic content and radical scavenging activity of the fortified yoghurt.

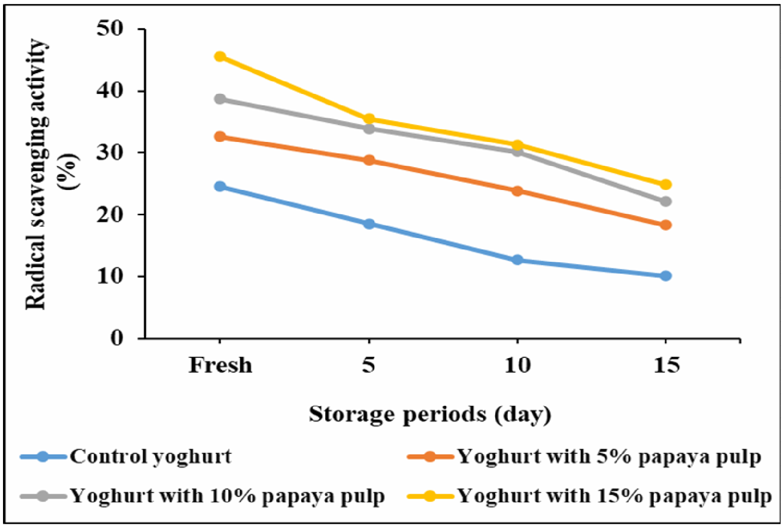

Fig. (1): Radical scavenging activity of yoghurt fortified with papaya fruit pulp during 15 days of storage at 5° C

pH of stirred yoghurt

Fig. (2) illustrates the pH values of stirred yoghurt treatments influenced by adding papaya pulp during 15 days of storage at 5°C. It was obvious that the effect of papaya pulp on pH values was significant. The addition of 10 and 15% papaya pulp caused a significant decrease in the pH values of stirred yoghurt samples compared to the control. This can be ascribed to a decrease of papaya pulp pH (4.2-4.84) **(Zaman *et al.*, 2006, and Ebrahim *et al.*, 2024).** These findings align with the research of **El-Loly *et al*. (2024)**, who detected that pH values decreased significantly in flavored processed cheese by increasing the papaya ratio. It was also observed that the values of pH in all treatments significantly decreased as the storage period progressed, reaching its lowest point by the 15th day. This decrease was attributed to the post-fermenting process of lactose to lactic acid. These conclusions are matched with those of **Farahat & Batawy (2013), and Blassy *et al*. (2020)**.

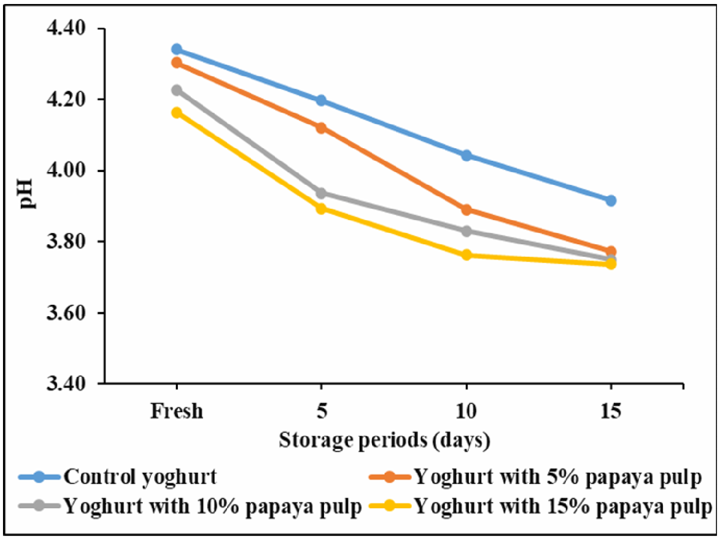

Fig. (2): pH values of yoghurt fortified with papaya pulp during 15 days of storage at 5° C

The titratable acidity of stirred yoghurt

As exposed in Fig. (3), titratable acidity increased with the higher ratio of papaya pulp in the stirred yoghurt samples. This increase was significant in stirred yoghurt samples fortified with 10 and 15% papaya pulp compared with the control samples. This can be ascribed to the elevation of papaya pulp acidity, which reaches 0.90% citric acid/100 g fresh weight **(Ebrahim *et al*., 2024)**. Moreover, the acidity content for all samples increased significantly through the storage. This can be explicated by the fact that fruit pulp contains higher levels of critical nutrients such as simple sugars, minerals, and vitamins, which may promote the development and activity of yoghurt starters **(Al-Farsi and Lee, 2008).**

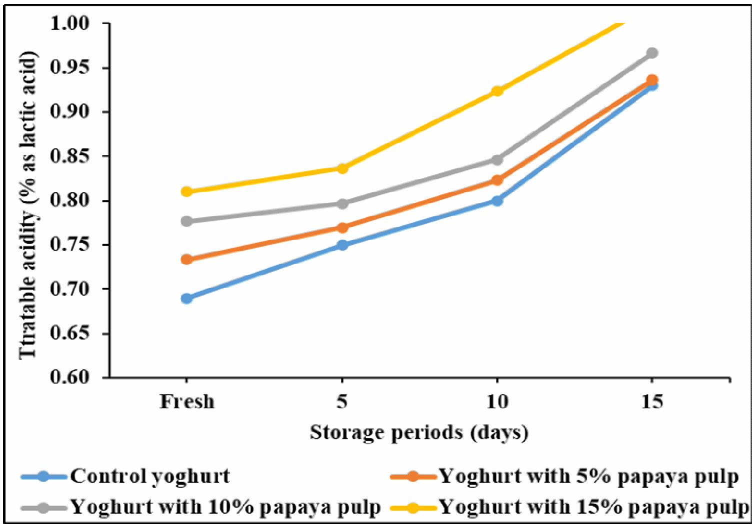

Fig. (3): Titratable acidity (% as lactic acid) of stirred yoghurt during 15 days of storage at 5° C

Rheological properties of stirred yoghurt

Whey syneresis values of yoghurt during 15 days of storage at 5° C

The whey syneresis of stirred yoghurt samples was significantly ($P \leq 0.05$) influenced by both the fruit ratio and the storage time. As shown in Table (4), adding 5% papaya pulp resulted in a significant increase in syneresis values, by increasing the pulp percentage to 10 and 15%, the syneresis values decreased significantly. The reduction in syneresis by increasing pulp percentage may be owing to the water-absorbing capacity of the solids present in the fruit, which helps reduce syneresis **(Mahmood *et al*., 2008)**. During storage periods, the syneresis values of stirred yoghurt decreased up to the 10th day of storage and increased on the 15th day. The decline in syneresis during storage may be a result of the reduction in pH **(Khalil *et al*., 2022)**. At the same time, the insufficient storage conditions could be conceivable reasons of augmented syneresis value in yoghurt. Additionally, several factors influence the rate of whey syneresis, including the type of starter cultures, homogenization (single or dual-stage), protein-hydrolyzing, production of extracellular polysaccharides, inoculation rate, optimization of the heat treatment process, incubation temperature, and the two-step cooling process **(Rani *et al*., 2012 and Arab *et al*., 2023)**. A similar observation was reported by **Bakirci and Kavaz (2008).**

From the same table, it could be noted that viscosity values increased significantly as the papaya pulp ratio in stirred yoghurt was increased. The stirred yoghurt containing 15% papaya pulp had the highest viscosity (5326.67 CP) compared with the control sample (4763.33 CP). This may be owing to the high content of carbohydrates and total solids in papaya pulp **(Akin and Konar, 1999)**. The higher content of total solids and fiber in papaya contributes to the increased viscosity and improved textural attributes of flavored yoghurt. This can be associated with the pectin and fructose in the fruit pulp, which supports and enhances the consistency and viscosity of the yoghurt, resulting in a better textural quality compared to the control **Othman *et al*., 2019)**.

Furthermore, viscosity in the control and other treatments increased as the storage period progressed. This increase was substantial at the end of the storage for both the control and other treatments. The rise in viscosity during storage may be owing to the formation progress of gel structure, as well as variations in protein-protein bonds within the three-dimensional protein network of the yoghurt and their subsequent rearrangement

(Shahbandari *et al*., 2016). These results are matched with **Blassy *et al*. (2020)** who indicated that fortifying yoghurt with some fruit pulp resulted in increased viscosity values.

Table (4): Changes in whey syneresis (ml/100g) and viscosity (cp) values of stirred yoghurt during 15 days of storage at 5° C

Items	Storage periods (day)	Control yoghurt	Yoghurt with papaya fruit pulp		
			5%	10%	15%
Whey syneresis	Fresh	29.00± 1.00^{C,a}	36.00± 2.00^{A,a}	34.33± 1.53^{AB,a}	31.33± 2.52^{BC,a}
	5	22.67± 0.58^{C,c}	31.00± 3.61^{A,bc}	29.00± 2.65^{AB,b}	25.33± 2.52^{BC,b}
	10	20.00± 2.00^{B,c}	26.67± 2.52^{A,c}	25.00± 1.00^{A,c}	23.00± 3.61^{AB,b}
	15	25.67± 2.08^{B,b}	32.00± 2.00^{A,ab}	29.00± 1.73^{AB,b}	26.33± 1.15^{B,b}
Viscosity	Fresh	4763.33± 40.41^{D,d}	4990.00± 17.32^{C,d}	5200.00± 70.00^{B,c}	5326.67± 50.33^{A,d}
	5	5110.00± 10.00^{D,c}	5273.33± 25.17^{C,c}	5443.33± 51.32^{B,b}	5570.00± 36.06^{A,c}
	10	5383.33± 55.08^{B,b}	5493.33± 92.92^{B,b}	5520.00± 72.11^{B,b}	5806.67± 80.21^{A,b}
	15	5640.00± 43.59^{C,a}	5866.67± 41.63^{B,a}	5970.00± 95.39^{B,a}	6110.00± 26.46^{A,a}

Means indicated using uppercase letters in the same row are significantly different ($P \leq 0.05$).
Means indicated using lowercase letters in the same column are significantly different ($P \leq 0.05$).

Stirred yoghurt color

Table (5) presents the color attributes of stirred yoghurt containing papaya fruit pulp. The color of the stirred yoghurt was influenced by adding papaya pulp. The *L** values of all stirred yoghurt samples containing papaya pulp were significantly lower than those of the control sample. Inversely, the *a** and *b** values increased significantly with the addition of papaya pulp ratios in yoghurt. This may be due to the orange-red color of papaya pulp, the *a** and *b** are characteristics attributed to the carotenoids found in papaya., which led to rise in the red and yellow color of yoghurt containing papaya pulp **(Nwofia *et al*., 2012, and Zuhair *et al*., 2013)**. Similar findings were found by **Cakmakci *et al*. (2014), and Othman *et al*. (2019)** when incorporating carrot juice and papaya puree into stirred yoghurt, respectively.

Table (5): Color parameters (L^*, a^*, b^*) of stirred yoghurt

Hunter values	Control yoghurt	Yoghurt with papaya fruit pulp		
		5%	10%	15%
L^* value	87.75± 0.03^A	83.96± 0.02^B	80.56± 0.06^C	78.48± 0.09^D
a^* value	-3.34± 0.03^D	-0.72± 0.02^C	0.95± 0.02^B	1.03± 0.01^A
b^* value	12.87± 0.04^D	14.99± 0.02^C	16.90± 0.03^B	18.52± 0.02^A

L^*: lightness, a^*: redness, b^*: yellowness.
Means indicated using uppercase letters in the same row are significantly different ($P \leq 0.05$).

Sensory evaluation of stirred yoghurt

Sensory evaluation is a critical aspect in assessing consumer receptiveness of healthy foods. The widespread approval of yoghurt largely relies on its sensory properties, which play a crucial role in trade promotion and sustaining consumer preference **(Bayarri *et al.*, 2011)**. Table (6) displays the average sensory profile scores for stirred yoghurt fortified with papaya pulp. No substantial difference in the body and texture scores was found between the control and yoghurt containing 5 and 10% papaya pulp. While a significant different was noted between the control stirred yoghurt and that fortified with 15% papaya pulp. The highest (29.40) body and texture scores were recorded in the control.

Regarding appearance and color, a substantial difference between the control and yoghurt treatments containing 15% papaya pulp. The highest appearance and color scores were observed in the control followed by yoghurt fortified with 5 and 10% papaya pulp. Additionally, no significant different was observed in acidity scores between the control and the fortified yoghurt samples. The highest (9.50) score of acidity was observed in the yoghurt fortified with 15% papaya.

Regarding flavor, no significant different was noted between the control-stirred yoghurt and yoghurt fortified with papaya pulp. Regarding overall acceptability, there was no significant different between the control and yoghurt containing 5 and 10% papaya pulp. A significant different was noted between the control and yoghurt containing 15% papaya pulp. Finally, all yoghurt fortified with 5, 10, and 15% papaya pulp were acceptable by panelists with 96.40, 95.30, and 93.00%, respectively compared with 97.20% of the control.

Table (6): Sensory evaluation of stirred yoghurt during 15 days of storage at 5° C

Items	Storage periods (day)	Control yoghurt	Yoghurt with papaya fruit pulp		
			5%	10%	15%
Body& texture (30)	Fresh	29.40± 0.55^{A,a}	28.60± 1.34^{AB,a}	27.90± 1.43^{AB,a}	27.20± 1.82^{B,a}
	5	29.20± 0.84^{A,a}	28.20± 0.57^{AB,a}	27.30± 1.44^{B,a}	26.70± 1.68^{B,ab}
	10	27.90± 2.51^{A,ab}	27.80± 1.04^{A,a}	26.70± 0.97^{AB,ab}	25.60± 1.52^{B,ab}
	15	26.30± 0.84^{A,b}	25.70± 0.97^{A,b}	25.10± 1.24^{A,b}	24.70± 2.11^{A,b}
Appearance and color (15)	Fresh	14.60± 0.55^{A,a}	14.40± 0.89^{A,a}	13.80± 0.84^{A,a}	12.60± 0.89^{B,a}
	5	14.20± 0.84^{A,a}	13.80± 1.64^{AB,a}	13.00± 1.22^{AB,ab}	12.20± 1.79^{B,a}
	10	13.40± 1.14^{A,a}	13.00±1.41^{A,ab}	12.00± 0.71^{A,bc}	11.80± 1.64^{A,a}
	15	12.00±1.00^{A,b}	11.80± 0.84^{A,b}	11,60± 1.14^{A,c}	11.40± 1.14^{A,a}
Acidity (10)	Fresh	9.40± 0.55 ^{A,a}	9.20± 0.45^{A,a}	9.40± 0.84^{A,a}	9.50± 0.55^{A,a}
	5	8.80± 0.84^{A,ab}	8.60± 0.89^{A,ab}	8.40± 0.89^{A,a}	8.80± 0.45^{A,ab}
	10	8.40± 0.89^{A,ab}	8.00±0.71^{A,b}	8.20±0.45^{A,ab}	8.20± 1.10^{A,b}
	15	8.00± 0.71^{A,b}	7.90± 0.22^{A,b}	7.30± 0.84^{AB,b}	6.80± 0.45^{B,c}
Flavor (50)	Fresh	43.80± 1.10^{A,a}	44.20± 0.45^{A,a}	44.40± 0.89^{A,a}	43.80± 1.30^{A,a}
	5	43.30± 0.97^{A,a}	43.40± 0.55^{A,a}	43.20± 1.30^{A,a}	43.40± 0.89^{A,ab}
	10	43.30± 1.20^{A,a}	43.20±1.10^{A,a}	43.00±1.58^{A,a}	42.80± 0.84^{A,ab}
	15	41.20± 1.10^{A,b}	41.40± 1.52^{A,b}	42.60± 1.67^{A,a}	42.40± 0.89^{A,b}
Overall acceptability (100)	Fresh	97.20± 2.17^{A,a}	96.40± 2.51^{AB,a}	95.30± 3.42^{AB,a}	93.00± 2.37$^{B, a}$
	5	95.50± 1.41^{A,a}	94.00± 2.37^{AB,ab}	91.90± 3.34^{B,ab}	91.10± 1.47^{B,ab}
	10	93.00± 1.46^{A,b}	92.00± 2.42^{A,b}	89.90± 2.01^{AB,bc}	88.40± 3.97^{B,bc}
	15	87.50± 1.58^{A,c}	86.80± 1.25^{A,c}	86.60± 2.86^{A,c}	85.30± 2.91^{A,c}

Means indicated using uppercase letters in the same row are significantly different ($P \leq 0.05$).
Means indicated using lowercase letters in the same column are significantly different ($P \leq 0.05$).

During storage, all sensory attributes were significantly lower on the 15th day of storage for all yoghurt samples compared to fresh samples. This is due to the fact that, at the initiation of the storage phase, all treatments of yoghurt were preferred, primarily owing to their stronger flavor and improved consistency. But, after 15 days, the yoghurt acidity raised, and the sensory scores of all samples began to decline (**Songul *et al*., 2012**). As the pH declined, the aroma and acidic taste intensified, resulting in a reduction of the overall flavor characteristics (**Tarakci, 2010**). **Farahat and El-Batawy (2013)** suggested that the reduction in sensory profile scores for all yoghurt samples after 15 days was attributed to the progress of acidity or the Bacterial metabolic products, which slightly affected the rheological and sensory properties of the product. These results align with **Matter *et al.* (2016)**, who exhibited that adding papaya pulp to stirred yoghurt improved the sensory attributes of the resulting product.

Microbiological examination results of control and stirred yoghurt

The data in Table (7) illustrate the total bacterial, *Streptococcus thermophiles, Lactobacillus delbrueckii spp. bulgaricus,* yeasts, molds and coliforms counts of stirred yoghurt fortified with papaya pulp during 15 days of storage at 5° C. The total bacterial count in stirred yoghurt containing deferent ratios of papaya pulp was lower than that in the control yoghurt through the storage period. Also, the total bacterial count decreased gradually with increasing percentages of papaya pulp and progressing storage periods. The stirred yoghurt samples containing 15% papaya pulp had the lowest count of total bacteria. This may be owing to the high content of phytochemicals which act as antimicrobials of bacteria growth in papaya pulp **(Leong and Shui, 2002)**, or due to the rise of sugar levels present in fruit juices, which promotes acidity development and reduces the development rate of certain bacteria **(Moustafa *et al*., 2016).**

Fortified of stirred yoghurt with papaya pulp reduced the *Streptococcus thermophilus and Lactobacillus delbrueckii spp. bulgaricus* counts compared to the control stirred yoghurt. The high counts of *Streptococcus thermophiles* and *Lactobacillus delbrueckii spp. bulgaricus* were $61\times10^7$and 31×10^7cfu/ml, respectively for the control stirred yoghurt. The overall trend of these observations is consistent with **Prescott *et al*. (2005)** results, which detailed that lactic acid bacteria grow and active optimally under slightly acidic conditions, with an ideal pH range between 4.5 and 4.6. Additionally, the pH value and lactose concentration of flavored stirred yoghurt samples may also affect the growth of lactic acid bacteria. Similar results were established by **Atwaa *et al*. (2019)** who discovered that the *S. thermophilus* and *L. acidophilus* counts declined through the cooled storage for up to 14 days. Therefore, fortifying yoghurt with fruit juices reduced the survivability of lactic acid bacteria during storage **(Teshome *et al*., 2017)**.

The yeasts and molds were not noticed on the fresh time, 5th and 10th days of storage periods for the control and yoghurt treatments, but it was noticed on the 15th day of storage. The lowest yeasts and mold count was noticed in the control yoghurt. The yeasts and molds count raised gradually with rising percentages of papaya pulp. This may be owing to the high content of fruit pulp sugar, which improves yeasts and molds growth **(Ali, 2018)**. Additionally, the coliform bacteria were not noticed in the all stirred yoghurt samples, and during all storage periods. These results are in agreement with those reported by **Matter *et al*. (2016).**

CONCLUSION

This study concludes that the addition of papaya fruit pulp significantly influenced the physicochemical, sensory, and functional properties of stirred yoghurt. Promoting the use of papaya fruit in food products is highly recommended due to its functional benefits and nutritional value. Furthermore, additional research is encouraged to explore the potential of papaya fruit in enhancing the processing properties of dairy products.

Table (7): Changes in some bacterial groups (cfu/g), yeasts, and molds of yoghurt fortified with papaya juice during 15 days of storage at 5° C

Components	Storage periods (day)	Control yoghurt	Yoghurt with papaya juice		
			5%	10%	15%
Total bacterial count (cfu× 10^7)	Fresh	$121.00\pm 3.61^{A,a}$	$57.67\pm 3.51^{B,a}$	$36.67\pm 2.52^{C,a}$	$30.33\pm 4.51^{C,a}$
	5	$81.33\pm 4.04^{A,b}$	$41.00\pm 6.56^{B,b}$	$25.00\pm 1.73^{C,b}$	$19.00\pm 4.00^{C,b}$
	10	$67.00\pm 4.00^{A,c}$	$31.00\pm 1.00^{B,c}$	$17.67\pm 1.53^{C,c}$	$8.67\pm 0.58^{D,c}$
	15	$42.00\pm 1.73^{A,d}$	$19.33\pm 2.52^{B,d}$	$12.33\pm 1.53^{C,d}$	$8.00\pm 1.00^{D,c}$
***Streptococcus thermophiles* (cfu× 10^7)**	Fresh	$61.00\pm 1.73^{A,c}$	$59.00\pm 2.65^{A,c}$	$49.33\pm 1.15^{B,c}$	$37.67\pm 1.15^{C,b}$
	5	$85.33\pm 2.31^{A,a}$	$78.00\pm 3.00^{B,a}$	$73.00\pm 1.73^{C,a}$	$61.00\pm 1.00^{D,a}$
	10	$75.33\pm1.15^{A,b}$	$71.67\pm 1.53^{B,b}$	$69.00\pm1.00^{C,b}$	$60.00\pm 1.00^{D,a}$
	15	$45.00\pm 1.00^{B,d}$	$49.33\pm 3.06^{A,d}$	$42.00\pm 1.73^{B,d}$	$35.33\pm 1.53^{C,c}$
***Lactobacillus bulgaricus* (cfu× 10^7)**	Fresh	$31.00\pm 3.61^{A,d}$	$31.00\pm 4.00^{A,d}$	$28.00\pm 4.36^{AB,c}$	$21.00\pm 5.57^{B,c}$
	5	$57.33\pm 1.53^{A,c}$	$50.00\pm 2.00^{B,c}$	$43.33\pm 4.16^{C,b}$	$36.33\pm 2.31^{D,b}$
	10	$85.00\pm 4.58^{A,b}$	$76.67\pm 3.51^{A,a}$	$68.00\pm 4.58^{B,a}$	$59.33\pm 5.03^{C,a}$
	15	$96.67\pm 5.05^{A,a}$	$59.00\pm 4.58^{B,b}$	$38.00\pm 5.57^{C,b}$	$32.00\pm 6.24^{C,b}$
Coliforms count (cfu ×10^2)	Fresh	ND	ND	ND	ND
	5	ND	ND	ND	ND
	10	ND	ND	ND	ND
	15	ND	ND	ND	ND
Yeasts, molds count (cfu×10^2)	Fresh	ND	ND	ND	ND
	5	ND	ND	ND	ND
	10	ND	ND	ND	ND
	15	3.00 ± 1.00^{D}	14.00 ± 3.61^{C}	25.00 ± 4.58^{B}	38.00 ± 2.65^{A}

Means indicated using uppercase letters in the same row are significantly different ($P \leq 0.05$).
Means indicated using lowercase letters in the same column are significantly different ($P \leq 0.05$).

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تقييم جودة الزبادى المُقلب المدعم بلب فاكهة الباباز

عزة صبيح عبد الغنى*

الملخص العربي:

فى هذا البحث، تم تصنيع زبادي مقلب مدعم بلب فاكهة الباباز بمعدل ٥ و ١٠ و ١٥٪، وقد تم تحليل الخواص الكيميائية والفيزيائية والحسية والميكربيولوجية لجميع العينات من الزبادي المدعم والكنترول بعد التصنيع مباشرة وخلال فترة التخزين على ٥^0 م لمدة ١٥ يوم. وقد أظهرت النتائج زيادة محتوى كلا من الجوامد الصلبة الكلية والرماد والألياف وانخفاض محتوى البروتين والدهن في الزبادي المدعم مقارنةً بالعينة الكنترول، كما زاد محتوى المواد الفينولية الكلية والنشاط المضاد للأكسدة للزبادي المقلب باضافة لب الباباز وبزيادة نسبة اللب المضافة، وأدى إضافة لب الباباز بنسبة ١٠ و ١٥٪ الى انخفاض معنوى في قيم الأس الهيدروجيني مقارنةً بالزبادي الكنترول، كما زادت نسبة الحموضة بزيادة نسبة اللب المضافة، وكانت أعلى قيم لانفصال الشرش في الزبادي المدعم بلب الباباز بنسبة ٥٪، كما اعطى الزبادي المدعم بنسبة ١٥٪ أعلى قيم لزوجة مقارنة بالمعاملات الاخرى، كما تأثر لون الزبادي المقلب بإضافة لب الفاكهة، حيث انخفضت قيم اللون الابيض، لكن زادت قيم اللون الاحمر والاصفر معنويا بزيادة نسب اللب المضافة، وكانت جميع عينات الزبادي المدعم بلب الباباز بنسبة ٥ و ١٠ و ١٥٪ مقبولة حسيًا بنسب ٩٦.٤٠ و ٩٥.٣٠ و ٩٣.٠٠٪ على التوالي، و كانت أعداد بكتريا *S. thermophilus* و*L. bulgaricus* في اليوم الخامس من فترة التخزين هى الأعلى لجميع المعاملات. وأخيرًا، وأشارت نتائج هذه الدراسة الى أن إضافة لب الباباز إلى الزبادي المقلب أدى إلى تحسن معنوى في الخصائص الفيزيائية والكيميائية والنشاط المضاد للأكسدة في الزبادي.

الكلمات المفتاحية: الزبادى المُقلب، لب فاكهة الباباز، النشاط المضاد للأكسدة، الخصائص الريولوجية

* قسم علوم الأغذية (شعبة الاقتصاد المنزلى الريفى) - كلية الزراعة - جامعة الزقازيق – مصر.