Enhancing the Nutritional value and Functional Properties of Yogurt Fortified with Kiwi Pulp

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ABSTRACT

Yogurt is a well-known fermented product. It is also utilized as a nutritious food item due to its nutritional value, tasteful, and improving the digestibility of the milk. Kiwi fruits are one of the world's healthiest fruits because of their high content of dietary fiber, and antioxidant compounds that enhance the immune system and promote intestinal health. Therefore, this study aimed to investigate the impact of supplementation of different percentages of Kiwi pulp fruit on the physio-chemical, sensory characteristics, and antioxidant activity of treated yogurt throughout cold storage for 14 days. T1, T2, and T3, three yogurt treatments are made from pasteurized cow's milk fortified with Kiwi pulp at rates of 5,10, and 15% respectively, and yogurt without additives as a control sample (C). Results revealed that fortified yogurt with Kiwi pulp had significant differences compared to blank yogurt. T1 has the highest values for physio-chemical properties, viscosity, and texture profile analysis. Furthermore, both T1 and T2 exhibited high overall acceptability for sensory properties. Interestingly, there is a significant increase in antioxidant activity and iron content of the fortified yogurt supplemented with Kiwi pulp. Thus, the Kiwi-fruit addition not only enhanced the physiochemical and sensory properties of yogurt but also improved its nutritional value.

Keywords: Yogurt; Kiwi fruit; Antioxidant; Physio-chemical, Sensory properties.

INTRODUCTION

Recently functional foods such as low-fat and high-fiber content foods have a great conscious due to their impact on promoting health including reduction and prevention of different types of chronic diseases. Fruits and vegetables are the highest sources of dietary fiber and antioxidants that help extend the shelf life and change the structural and physio-chemical features of fortified foods as well as affect their sensory properties (Figuerola *et al.,* 2005 and Ajila *et al.,* 2008). Consumption of fortified food products with fruits is rising to enhance health and nutritional value coming from decreasing the risk of diseases as well as preventing cancer and depression disease (Angelino *et al.,* 2019).

Fruit intake has also been inversely associated with perceived stress (Radavelli-Bagatini *et al.,* 2021). Additionally, fortified food with fruits and vegetables helps reduce glycemic response which plays a critical role in managing glucose metabolism and dysregulated lipid (Havel, 2005 and Stanhope, 2012). Some fruits that are used in fortified food products have uric acid content that improves the metabolismof hepatic fructose and is also related to metabolic syndrome such as cardiovascular and hypertension diseases (Stanhope *et al.,* 2009 and Laughlin, 2014).

Yogurt is one of the synthesized foods via milk fermentation, which occurs by using bacterial cultures. These bacterial cultures are *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. This causes lactose fermentation and formation of lactic acid subsequently interacting with milk proteins producing yogurt with a specific texture and taste. Furthermore, lactic acid causes a reduction of pH and coagulation of milk proteins, which stipulates a feature gel-like look to the yogurt (Abdalla *et al.,* 2015 and Kanauchi, 2019). There are many factors affecting the characteristics of yogurt including type and quantity of starter cultures, raw materials used in manufacturing, type of milk, likewise manufacturers' requirements such as temperature, incubation conditions, and other situations (Corrêa *et al.,* 2018). Subsequently, these factors impact the properties of yogurt as texture and physio-chemical properties (Kanauchi, 2019).

Consumption of yogurt has risen globally as a result of its exceptional characteristics such as high nutritional value, likewise its therapeutic features (Mckinley, 2005). Yogurt is a digestible product containing multiple essential components such as carbohydrates,

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proteins, fat, vitamins, minerals calcium, and phosphorous (Vahedi *et al.,* 2008). Additionally, yogurt has a high consumption rate because it promotes human gut microbiota health alongside protection from many digestive problems and enhances the immune system. Moreover, yogurt is considered a functional product that contains essential nutrients for growth in a bio-available form that can easily be absorbed and used in the body. Yogurt provides the body with milk proteins that have a higher biological value, along with almost all the essential amino acids needed for maintaining good health. It is advisable for individuals with lactose intolerance as the fermentation process reduces the original lactose content in the milk by 20-30% (Weerathilake *et al.,* 2014).

Generally, there are numerous categories of yogurt such as set, stirred, dried, and drinking yogurt (Gahruie *et al.,* 2015). Yogurt is processed by using appropriate industrial production ways via modification of the processes themselves, particularly supplementation and fortification of yogurt with other food products or nutrients. Fortification is the process of adding, enhancing, or supplementing food with more nutrients. Yogurt has been fortified with different kinds of foods to improve its nutritional value and increase its marketing as well as these ingredients have affected the physicochemical properties, microbial characteristics, and storage stability of the yogurt.

Yogurt could be fortified with organic or inorganic food ingredients, fruits, vegetables, or animal products to increase its nutritional value or enhance its features such as physicochemical characteristics, and sensory properties to raise merchantable (Santillán-Urquiza *et al.,* 2017; Szajnar *et al.,* 2018 and Harmela *et al.,* 2022).

For instance, adding fruits, vegetables, nuts and cacao to the yogurt enhanced its flavor (Roy *et al.,* 2015). Indeed, fruit additives are most utilized in yogurt fortification because they increase sensory qualities and overall acceptability (Najgebauer-Lejko, 2014). Additionally, fortified yogurt with fruits strengthened consistency and viscosity, which boosts the sensation in the mouth because of their content of pectin and sugar (Mora and Dando, 2021). Likewise, casein is reversely absorbed via pectin raising steric repulsion, and decreasing the aggregation (Nongonierma *et al.,* 2007 and Çakmakçi *et al.,* 2012). Fruits are a source of nutrients that reinforce human health (Ahmad *et al.,* 2022). Furthermore, fruits are rich sources of dietary fiber, antioxidant compounds such as phenolic, and carotenoids, and oligosaccharides, a type of prebiotic fibers that trigger the colonization of gut microbiota (Fernandez and Marette, 2017). Many fruits are used for yogurt fortification such as pears, strawberries, and dates (Arslan & Özel, 2012 and Senadeera *et al.,* 2018). Furthermore, this fortified yogurt plays a crucial role in boosting the body's immune system by combating harmful substances like reactive oxygen species and reactive nitrogen species. These substances are produced by our body through various internal processes and can be triggered by different physiological or pathological factors (Lobo *et al.,* 2010). Fruits are added to the yogurt formula in different forms as pulp, juice, or syrup (Matter *et al.,* 2016).

Besides, fruits are used to produce probiotic yogurt with high phenolic component content and antioxidant activity which enhances the health benefits of fortified yogurt (Sahingil and Hayaloglu, 2022). This addition to fermented dairy products affected the incubation period, starter culture growth, acidification rate, syneresis, and viscosity this could be due to total solids of fruit pulp especially soluble fibers that cause absorption of water as well as enhancement of the viscosity (Dimitrellou *et al.,* 2020). The fortification of yogurt with fruits influenced its pH values and acidity rates and the growth of the microflora subsequently yogurt’s shelf life and maintains the sensory characteristics of yogurt as a result of inhibition of spoilage microorganisms (Kamber and Harmankaya, 2019).

Kiwi fruit (*Actinidia deliciosa*) is one of the richest sources of nutrients, that possesses great economic value which increasing the consumer’s and manufacturer's attention (Porat *et al.,* 2018). Kiwi fruit contains 1.14% protein, 3.0% fiber, 14.66% carbohydrate and 92.8% vitamin C (Wilson *et al.,* 2018). Besides, Kiwi fruit has a significant amount of minerals (potassium, phosphorus, iron), a high level of active enzymes (Kaur *et al.,* 2010), vitamin C, dietary fiber, vitamin E, and folate (Ahmad *et al.,* 2022). Moreover, Kiwi fruit contains antioxidant compounds such as ascorbic acid, polyphenols, and phenolic acids that reduce the risk of some diseases such as arteriosclerosis, cardiovascular and cancer (Park *et al.,* 2009). The ascorbic acid content is the key nutrient of Kiwi fruit that increases the efficiency of the immune system, improves iron bioavailability, enhances feelings of well-being, and mitigates fatigue symptoms (Fernandez and Marette, 2017). Dietary fibers in Kiwi fruits can be fermented and adjust digestion processes as Kiwi fruit extract contains significant components such as actinidin and pepsin that subsidy protein digestion in both the stomach and small intestine (Arslan and Özel, 2012).

Additionally, Kiwi fruit is an excellent source of potassium which helps people who suffer from hypertension. Similarly, Kiwi fruit has a high amount of dietary folate and bio-available vitamin E (Senadeera *et al.,* 2018). Kiwi fruit contains several unique proteins that have functional properties such as actinidin and

swelling (Lobo *et al.,* 2010). Fermentation by lactic acid bacteria is an ancient, cost-effective, and highly valuable biotechnological technique utilized in the preservation of fortified food products with fruits to ensure safety and prolong shelf life, while also enhancing nutritional content and flavor (Septembre-Malaterre *et al.,* 2018). Through the process of Lactobacillus fermentation, the nutritional density was enhanced as a result of reducing the sugar content, raising the levels of protein and peptide, and reinstating the levels of vitamin C (Zang *et al.,* 2021).

More importantly, through fermentation, the antioxidant activity could be changed (Singh *et al.,* 2023) showed that adding different levels of Kiwi fruit pulp to the yogurt enhanced the overall acceptability sensory score and increased its content of vitamin C and unsaturated fatty acids, reduced pH values, and increased syneresis (Singh *et al.,* 2023). In another study, Kiwi fruit addition played a critical role in ice cream making by affecting both the pH pre-adjustment and pre-heating of the aqueous fractions from purees (Sun-Waterhouse *et al.,* 2013). Health-beneficial phytochemicals were detected in Kiwi fruit ice cream because of the high percentage of Kiwi pulp (49% v/v) curdling of the ice cream mix and separation of Kiwi fruit juice during the pasteurization processes and aging steps due to the undesired enzyme activities in fortified ice cream made via Kiwi puree.

Fortification of yogurt with Kiwi fruit puree at different levels (2, 4, and 6%) significantly increased radical scavenging activity (RSA) and the total phenol content (TPC) in the fortified samples throughout the storage period when compared to the control plain yogurt (Soliman and Shehata, 2019). Also, Kiwi fruit juice was added to reconstituted milk at different percentages of 5%, 10%, and 15% (v/v) in the manufacture of fermented milk, which caused a significant rise in the growth of starter bacterial cultures, modified the titratable acidity and reinforced rheological characteristics of the fortified fermented milk (Su *et al.,* 2018). Furthermore, Kiwi juice is also used to fortify fermented milk as a source of hypoglycemic agents.

Recently, there has been a great interest in fortified yogurt with a natural source of antioxidants to protect and prevent different diseases (Senadeera *et al.,* 2018). These antioxidants improve the features of products by preventing the peroxidation of lipids as well as protecting yogurt peroxidability which in turn increase the shelf-life of products. The addition of fruit as a natural source of antioxidants to yogurt enhanced the antioxidant potential of yogurt and likewise raised the overall acceptability of fortified products (Ogunyemi *et al.,* 2021). Thus, the current study amid to evaluate the utilization of Kiwi fruit pulp at different levels to enhance the functional properties Physicochemical, rheological, sensory, and antioxidant activity of yogurt samples.

MATERIAL AND METHODS

Raw full-fat cow's milk 3% fat, 11.5 % total solids (TS) was obtained from the Alexandria University, farm of the Faculty of Agriculture, starter bacterial cultures, and freeze-dried lactic culture for direct vat set (DVS). (Express 0.2, thermophilic yogurt culture Yo-Flex Express), consisting of *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus thermophilus* were obtained from Chr. Hansen Lab., Denmark, and fresh Kiwi fruit was obtained from the local market of Tanta, Egypt. The Kiwi pulp's TS content is about 16.57% and the pH value is 3.20 which determined by preprared and dried the Kiwi fruit at 45˚C/6-7 h, according to the methods described by Engelhart *et al.* (2002).

Preparation of Kiwi pulp:

Kiwi fruits were supplied by a local producer. Kiwi fruit pulp was prepared according to Soliman and Shehata (2019). Briefly, Kiwi fruit was washed and then the pulp was obtained from the crushed fruit peeled manually then blended using an electric blender. The homogenate was heated at 85 °C for 10 min. After that cooled and stored at 4 ± 1 °C until used. The total solids and pH value were determined according to the method recommended by A.O.A.C. (2000).

Yogurt manufacture:

Yogurt was processed in the dairy pilot laboratory of the food science and technology department, at Tanta University. Yogurt was produced following the published procedure (Tamime and Robinson, 2007). Raw full-fat cow´s milk was pasteurized at 90 °C for 10 min, then the temperature was reduced to 42 ºC by cooling with cold water. Further, the pasteurized milk was divided into four portions. One batch of milk was taken as Control yogurt (CY), while the other partitions were mixed with Kiwi pulp at various percentages 5 % (T1), 10 % (T2), and 15% (T3) w/w. Subsequently, commercial freeze-dried yogurt lactic bacterial culture (DVS) for the direct VAT set was added at the dose recommended by suppliers (0.02%). Then all yogurt treatments were incubated at 44 ±1 °C for 3-4 h. and stored for 14 days at 5 ±1 °C for further analysis.

Physicochemical analysis of Yogurt:

Physicochemical analysis of yogurt treatment samples was investigated according to the Association of Official Analytical Chemists (A.O.A.C. 2020). The pH value of yogurt samples was measured by a pH meter (a pH meter Mi 151 PH /ORP /Temperature Bench Meter). The fat analysis was conducted using the

Gerber method, while the determination of total nitrogen was done through the Kjeldahl method. The nitrogen content was then converted to proteins using the 6.38 factor. The ash content of yogurt samples was determined by subjecting them to muffle furnaces at a temperature of 550 °C. The calculation of total carbohydrates involved subtracting the combined amounts of liquid, fat, ash and protein from the overall composition of the sample.

Textural Analysis:

Textural characteristics of treated yogurt samples were evaluated using the back extrusion method that was carried out using a texture analyzer (Stable Micro Systems Ltd., Godalming, UK) equipped with a 25 kg load cell and an extrusion disc (35 mm), running the test at a fixed speed of 1 mm s^{-1}, to a depth of 25 mm. 100 g of each treatment yogurt sample was stored overnight at 8 °C in cups of 100 mL to allow the samples to equilibrate according to Iličić *et al.* (2014). The results were given as the mean of three replicates.

Determination of Viscosity:

Viscosity is known as the resistance of a material as opposed to distortion and particularly in yogurt refers to the viscous fluid of samples (Lal *et al.*, 2006). The viscosity of yogurt was measured by an oscillatory viscometer (VR 3000M YR Viscometers, Spain) using spindle L^3 at 60 rpm speed. The viscometer probe was placed in the yogurt sample cup, and viscosity was assessed at 10 ±2 °C in the up mode at shear rates ranging from 37 - 1238 1/s.

Sensory Evaluation:

The sensory evaluation of yogurt treatments was conducted at 0, 7, and after 14 days of storage. The yogurt samples were evaluated by a team of panellists from the Department of Food Science and Technology at Tanta University. These panellists have extensive experience and knowledge in scientific food evaluation. The yogurt samples were provided in labelled cups at room temperature, with four criteria (appearance, texture, flavour, and overall grade). The evaluation was conducted using a points system with minor modifications (Crispín-Isidro *et al.*, 2015). Sensory evaluation scores: extremely unacceptable = 1; unacceptable-barely acceptable = 2–4; acceptable-very acceptable = 5–9; extremely acceptable = 10.

Antioxidant Activity by DPPH radical scavenging activity:

Free radical scavenging activity (RSA) of the yogurt samples was determined using DPPH Assay (1, 1-diphenyl-2-picrylhdydrazyl free radical scavenging activity) (Brand-Williams *et al.*, 1995). Briefly, the control stock was prepared by adding 2 ml of DPPH to 1 ml of methanol. Next, 1 ml of extracts at various dilutions had 2 ml of 0.15 mM DPPH added to it. Following the mixing process, the tubes were left undisturbed for a duration of 30 minutes. The absorbance levels were then determined at a wavelength of 517 nm using a spectrophotometer from Pg T80+ in England. Three copies were utilized for each sample. Ultimately, the findings were presented as a percentage representing the activity of scavenging radicals.

$$\text{Radical scavenging activity \%} = \frac{(\text{A control} - \text{A sample})}{\text{Acontrol}}$$

Iron measurement:

Iron was determined using an Atomic Absorption Spectrophotometer (Pyeunican SP 1900) according to Jones *et al.* (1991). 0.5- 1.0 g of samples were transferred into 30 or 50-glass beakers. Then, beakers were placed in a cool muffle furnace and the temperature gradually increased to 550 °C, and the ashing was completed for 5 h. After that, the cool ash was dissolved in 5 ml 2 N HCL, mixed thoroughly, and stirred for 30 mi. The supernatant was filtered through Whatman no. 42 filter paper and rejected the first portions of the filtrates.

Ascorbic acid content:

Ascorbic acid was determined using a titrimetric method with 2, 6- di-chlorophenol indophenol reagent (A.O.A.C., 2010). A 10 g sample was combined with 20 ml of a 2% oxalic acid solution. The mixture was thoroughly mixed, then diluted to 100 ml using a 2% oxalic acid solution, and finally filtered. 10 mL of the filtered solution was titrated using a 0.01% solution of 2,6-di-chlorophenol indophenol. The last aspect was taken into account when the solution turned pink at 15. The calibration of the solution was done using a 0.05% ascorbic acid solution. The results were reported as mg of ascorbic acid equivalents per 100 g of fresh weight.

Volatile Organic Compounds Analysis:

The determination of volatile organic compounds (VOCs) of Kiwi fruit was carried out according to Engels *et al.* (1997) by solid-phase microextraction–gas chromatography-mass spectrometry (SPME-GC/MS) (Mora and Dando, 2021). In short, 5 grammes of a finely ground sample is placed in a 20-mL glass vial that is sealed with an aluminium cap and a PTFE-septum. The system was flushed with 150 mL/min of helium gas for 30 minutes at 42 °C, and any volatile components were collected on an absorbent trap, specifically a carbon trap (80 mg, 20-40 mesh, Supelco). The captured substances were moved onto a capillary column of a gas chromatograph, utilising the Chrompack PT1 injector, through the application of heat to the trap oven. Starting at an initial temperature of 50 °C, the temperature will be increased at a rate of 6 °C

per min until it reaches 150 °C. It will then be held at this temperature for 2 min. Next, the temperature will be ramped up at the same rate to 200 °C, where it will be held for 0 minutes. Finally, the temperature will be increased to 280 °C at a rate of 6 °C per minute and held at this temperature for 2 min. The injection temperature is set at 280 °C, with a volume of 1L. The sample is split at a ratio of 20:1, and helium is used as the carrier gas. A solvent delay of 5.00 minutes is applied before the transfer temperature of 280 °C is reached. The source temperature is set at 200 °C. The experimental setup for the chromatographic separation and mass spectrometry has been established based on the work of Engels *et al.* (1997). The volatile compound compositions were determined through spectrum analysis, comparing the spectra with existing data, and comparing retention times with reference compounds. This was done using the Perkin Elmer/Model, Clarus 580/560 S gas chromatography-mass spectrometry (GC-MS) instrument. Analysis: Scan range of 50 to 620 Da using a column with specifications of Elite-5MS, 30 m length, 0.25 mm diameter, and 0.25 µm internal diameter.

Statistical analysis:

The experiment was conducted using a completely randomized design (CRD) with three replicates per treatment. The data underwent statistical analysis using the analysis of variance (ANOVA) followed by Tukey's honestly significant difference (HSD) test as a post-hoc analysis for mean comparison (p<0.05). PCA and correlation analysis were performed using the R program.

RESULTS AND DISCUSSION

Physicochemical properties of the raw cow milk were pH 6.7, acidity 0.17%, moisture 87.52%, fat 4.16%, protein, 3.32%, ash 0.74%, carbohydrate/lactose 4.26%, and SNF 8.37%.

Changes in the physiochemical properties of experimental yogurt treatments are shown in Figures (1–5). The basic composition of yogurt samples was determined over 14 days.

Gas Chromatography-Mass Spectrometry (GC- MS) analysis:

GC-MSanalysis of Kiwi pulp extracts revealed the presence of different bioactive compounds that could contribute to the therapeutic benefits compounds of the Kiwi fruit (Table 1 and Figure 1). The identification of these compounds was confirmed based on the peak area, retention time, and molecular formula. The main detected groups were 8.674% ketones (2-Propanone, 1,3-dihydroxy-, 2,5-Furandione, 3-methyl-, 2,4-Dihydroxy-2,5-dimethyl-3(2H)-furan-3-one, 1,2,4-Cyclopentanetrione, 3-methyl-, 2H-Pyran, tetrahydro-2-(12-pentadecynyloxy)-), 43.391% alcohols (1-Octanol, 2-nitro-, Pentanoic acid, 2-ethylcyclohexyl ester, Z-16-Octadecen-1-ol acetate), 14.563% acids (Quinic acid, Tetradecanoic acid, n-Hexadecanoic acid). There also, aldehydes likewise, Benzaldehyde, 4-fluoro- and 3.252% fatty acids (4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6- methyl), and 5.365% other compounds (2-Deoxy-D-galactose and d-Glycero-d-galacto-heptose) and 0.168 % of Alkanes and Alkenes (Oxirane, [(hexadecyloxy)methyl]-).

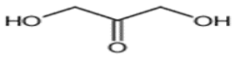
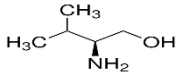
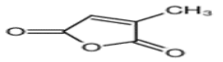
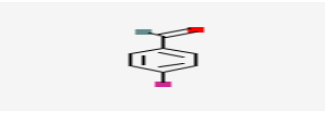
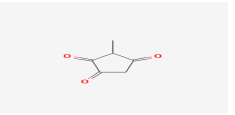
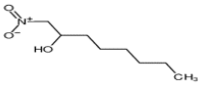
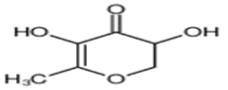
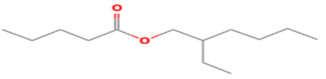
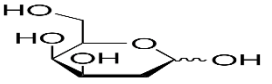
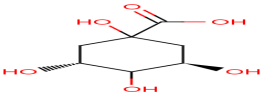
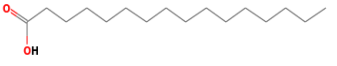
Total solids content of fortified yogurt:

Changes in the total solids (TS) content of yogurt after the addition of Kiwi pulp at various ratios during 14 days of storage period are illustrated in Table (2). Data revealed that there were significant differences (p< 0.01) among all yogurt treatments from the start day till the end of the storage period. (T1) treatment has significantly the highest TS content while T3-supplemented yogurt showed the lowest value among all treatments at 0 days. The same trend was revealed after 14 days of storage period. In contrast throughout the storage period, the TS content increased in all yogurt treatments. That approach was much observed with (T1) treatment.

Fat content of fortified yogurt:

According to Table (2), the addition of Kiwi pulp supplementation caused significant differences in the fat content of fortified yogurt among treatments at zero time and over the storage period (p<0.01). C and T1-fortified yogurt have the highest fat content compared to other treatments. Also, with the increase in the percentage of Kiwi pulp fortification, fat content decreased (p<0.05). This observation was obtained with T2 and T3 treatments. On the other hand, fat content was affected by the storage period of all treatments where it increased in yogurt T3 to 2.9% at the end of storage compared to 2.76 % at zero time.

Table 1.The volatile compounds of Kiwi-fruit extract

RT	COMPOUND STRUCTURE	COMPOUND STRUCTURE	MOLECULAR FORMULA
3.173	2-Propanone, 1,3-dihydroxy-		C_3H_6O
3.474	(S)-(+)-2-Amino-3-methyl-1-butanol		$C_5H_{13}No$
3.929	2,5-Furandione, 3-methyl-		$C_5H_4O_3$
4.814	2,4-Dihydroxy-2,5-dimethyl-3(2H)-furan-3-one		$C_6H_6O_2$
8.315	Benzaldehyde,4-fluoro-		C_7H_5FO
8.661	1,2,4-Cyclopentanetrione, 3-methyl-		$C_6H_6O_3$
8.851	1-Octanol, 2-nitro-		$C_8H_{17}NO_3$
10.731	4H-Pyran-4-one,2,3-dihydro-3,5-dihydroxy-6- methyl		$C_6H_8O_4$
12.907	Pentanoic acid, 2-ethylcyclohexyl ester		$C_{13}H_{26}O_2$
14.523	2H-Pyran,tetrahydro-2-(12-pentadecynyloxy)-		$C_{19}H_{34}O_2$
16.604	Z-16-Octadecen-1-ol acetate		$C20H_{38}O_2$
17.389	2-Deoxy-D-galactose		$C_6H_{12}O_5$
18.189	Oxirane, [(hexadecyloxy)methyl]-		$C_6H_{12}O_2$
19.645	d-Glycero-d-galacto-heptose		$C_7H_{14}O_7$
19.88	(1R,3R,4R,5R)-(-)-Quinic acid		$C_7H_{12}O_6$
21.48	Tetradecanoic acid		$C_{14}H_{28}O_2$
24.77	n-Hexadecanoic acid		$C_{16}H_{32}O_2$

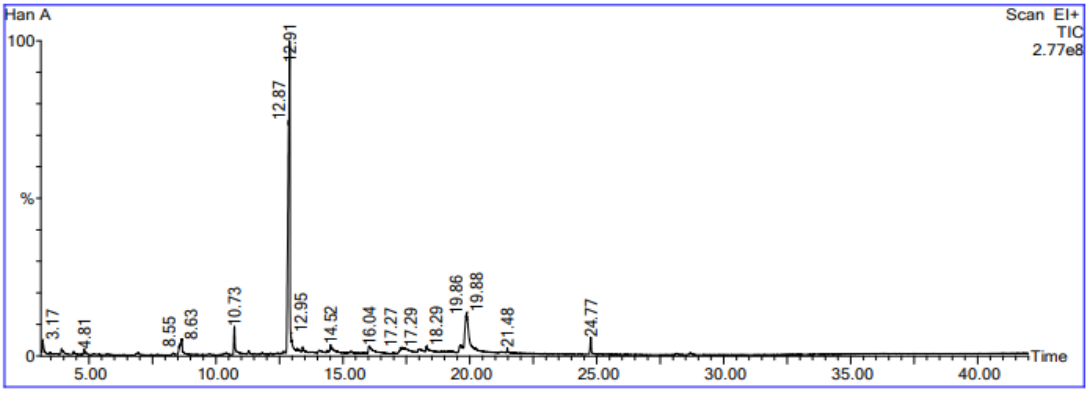


Fig.1. GCMS Chromatogram of the aqueous pulp extract of Actinidia deliciosa

Protein content of fortified yogurt:

The obtained results revealed that there were significant (p <0.05) differences in the protein percentage on fresh samples and during the storage period among all yogurt treatments (Table 2). Data displayed that the protein content was affected by the Kiwi pulp added where this addition reduced protein content in fortified yogurt. T2 and T3 treatments have lower protein content compared with C as well as T1 at zero time and throughout the storage period. On the contrary, during 14 days of storage period protein content was increased in all fortified yogurt treatments.

Table 2. The effect of different ratios of Kiwi pulp addition on physiochemical properties of yogurt

Storage days	Treatments	Total Solids	Fat	Protein	Ash	Carbohydrates	Iron	Ascorbic	R.S. A	pH
0	T1	14.61^{a}±0.08	3.38^{b}±0.02	3.53^{b}±0.02	0.98^{d} ±0.00	6.73^{c}±0.00	0.87^{a}±0.01	16.96^{f}±0.02	43.15^{a} ±0.36	4.46^{b} ±0.01
	T2	12.77^{c}±0.18	2.92^{c}±0.02	3.05^{c}±0.03	0.99^{bcd} ±0.00	5.82^{h}±0.00	0.57^{b}±0.00	18.54^{d}±0.02	38.88^{b} ±0.82	4.56^{b} ±0.01
	T3	11.91d±0.09	2.76d±0.03	2.79^{d}±0.02	0.99^{cd} ±0.00	5.38^{i}±0.00	0.61b±0.01	20.22^{a}±0.01	41.32^{ab} ±0.60	4.59^{a} ±0.01
	control	13.97^{b}±0.05	3.50a±0.00	3.60^{a}±0.00	0.92^{e} ±0.01	5.95^{f}±0.00	0.47^{c}±0.00	1.52^{a}±0.01	34.77^{c} ±0.27	4.44^{b} ±0.01
7	T1	14.74^{a}±0.03	3.42^{b}±0.04	3.55^{b}±0.00	0.99^{abc} ±0.00	6.77^{b}±0.00	0.91^{a}±0.00	16.86^{f}±0.03	39.41^{b} ±0.23	4.25^{b} ±0.01
	T2	12.92^{c}±0.13	2.98^{c}±0.02	3.14^{c}±0.06	0.99^{abc} ±0.00	5.82^{h}±0.00	0.60^{c}±0.01	18.35^{e}±0.03	28.84^{d} 1.22	4.21^{b} ±0.01
	T3	12.06^{d}±0.17	2.83^{d}±0.03	2.86^{d}±0.05	0.99^{abc} ±0.00	5.38^{i}±0.00	0.66^{b}±0.00	19.32^{b}±0.03	28.13^{d} ±0.69	4.40^{a} ±0.01
	control	14.20^{b}±0.05	3.55^{a}±0.03	3.63^{a}±0.01	0.99^{abc} ±0.00	6.02^{e}±0.00	0.56^{d}±0.00	1.44^{hi}±0.01	28.39^{d} ±0.43	4.23^{b} ±0.01
14	T1	14.86^{a}±0.05	3.43^{b}±0.03	3.57^{b}±0.01	1.00^{ab} ±0.00	6.87^{a}±0.00	0.94^{a}±0.01	16.74^{g}±0.02	31.06^{d} ±0.68	4.11^{b} ±0.01
	T2	13.03^{d}±0.18	2.98^{c}±0.02	3.13^{c}±0.04	1.00^{ab} ±0.00	5.92^{g}±0.00	0.62^{c}±0.00	18.26^{e}±0.02	21.67^{ef} ±0.95	4.10^{b} ±0.01
	T3	12.12^{c}±0.14	2.90^{d}±0.06	2.94^{d}±0.03	1.00^{ab} ±0.00	5.29^{j}±0.01	0.69^{b}±0.01	18.98^{c}±0.04	20.24^{f} ±0.58	4.17^{a} ±0.02
	control	14.38^{b}±0.16	3.57^{a}±0.02	3.63^{a}±0.02	0.99^{abc} ±0.00	6.20^{d}±0.00	0.59^{d}±0.00	1.40^{i}±0.02	24.33^{e} ±0.55	4.11^{b} ±0.02

Values represent the means ± standard error (means ± SE) of three biological replicates (n=3). Different letters in the same column indicate statistically significant differences between treatments at each time of storage(p<0.05).

Ash content of fortified yogurt:

The addition of Kiwi pulp at different percentages affected the ash content of fortified yogurt over the storage period as shown in Table (2). Fortified yogurt treatments have a significant increase (p<0.01) in ash content compared with control C. The ash content increased with increasing Kiwi pulp concentration and by prolonging storage periods. Furthermore, T3 has the highest ash content by the completion of the storage period compared with other yogurt treatments.

Carbohydrates of fortified yogurt:

The results showed that the carbohydrate content of fortified yogurt was significantly affected by the addition of various percentages of Kiwi pulp among treatments as illustrated in Table (2). Fortified yogurt (T1) has the highest carbohydrate content after 14 days of storage period (6.86), while (T3) showed the lowest (5.28) value among treatments. Also, data revealed that carbohydrate content affects the progress of the storage period. That was observed more in control yogurt (C).

Iron content of fortified yogurt:

Data illustrated that there were remarkable differences (p<0.01) in iron content among fortified yogurt experimental throughout the 14day storage period (Table 2). The control sample had a minimized iron content compared with other fortified yogurt treatments, not only of the fresh sample but also throughout the storage period. Results showed that the addition of Kiwi pulp was attributed to an increase in the iron content of fortified yogurt compared to control yogurt. Iron content was higher in T1 yogurt (0.94 mg/L) compared to other fortified yogurt samples. While fortified yogurt T3 has the lowest iron (0.69 mg/L) content until the end of the storage period the control yogurt C had the lowest iron content of all yogurt treatments (0.46 mg/L).

Ascorbic acid content of fortified yogurt:

The results demonstrated that there were great differences (p<0.01) in ascorbic acid content at the start date as well as during the storage period among all yogurt experiments (Table 2). T3 has the highest ascorbic acid at zero time (20.22 mg/100g) and until the end of the storage period (18.98 mg/100g) compared with other yogurt treatments. While control yogurt C), has the lowest content of ascorbic acid 1.52 and 1.40 at zero time and at the end of the storage period respectively.

Antioxidant activity of fortified yogurt (R.S.A):

The antioxidant activity or radical scavenging activity (R.S.A) of control and fortified yogurt samples are affected by the fortification of Kiwi pulp at different percentages as shown in Table (2). Data showed that there were significant differences among all yogurt samples (p<0.01). Yogurt supplemented with Kiwi pulp has higher antioxidant activity than control yogurt and this increase was more pronounced in the T1 sample at zero timeand after 14 days of storage from 43.15 %, to 31.06 % respectively. On the contrary, throughout the cold storage, antioxidant activity significantly lessened for all yogurt samples. The lowest antioxidant activity after 14 days of storage period was shown with T3 fortified yogurt as compared with other treatments.

pH values of fortified yogurt:

Table (2) shows the pH values of yogurt fortified treatments with Kiwi pulp. There were significant differences (p<0.01) in the pH values of yogurt treatments. pH values decreased during the storage period in all fortified and control yogurts. The fortification of Kiwi pulp caused a significant increase in the pH values of the fortified yogurt treatments. T2 and T3 recorded the highest pH values which were 4.56 and 4.58 respectively. However, at the end of the storage period, T2 had the lowest pH value 4.10.

Viscosity of fortified yogurt:

The viscosity of products has a great impact on their quality features (Yildiz *et al.,* 2013). The viscosity of fortified yogurt increased with the increases of Kiwi pulp addition ratio compared to control yogurt C. Increase in viscosity was noticed with yogurt at 1555.33 and 875.33 compared to other treatments as shown in Figure (2 E). Throughout the storage period of yogurt treatments, the viscosity significantly increased (p<0.01) for up to 7 days then decreased at the end of the storage period. The viscosity in yogurt treatments C, T2, and T3 were 681.33, 470.33, and 284.66 respectively. While the viscosity of T1 increased to 875.33 until the end of the storage period.

Texture profile analysis of fortified yogurt:

The texture of fermented products affects their structure. Also, the features of rheological and texture of fermented products are based on their adjustment structural as well as microstructure of the protein reticulum (Delikanli and Ozcan, 2017). The results of texture parameters (Firmness, Adhesiveness, and Consistency) of the control and fortified yogurt samples are shown in Figures (2F, G, I). Firmness or hardness is considered the most significant factor in evaluating the texture properties of the yogurt. It is considered the necessary force to complete a convinced distortion and is regarded as a measure of the hardness of the yogurt (Mudgil *et al.,* 2017).

As illustrated in Figure (2E) firmness value of the control yogurt was 252.0, while, the firmness values of other treatments were 305.66, 156.66, and 130.0 g for

T1, T2, and T3, respectively at the fresh point. As shown in the Figure (2F), fortified yogurt samples with Kiwi pulp affected the firmness of the yogurt experiment. The T1 samples had the highest firmness values than other fortified yogurt samples at zero time and after the storage period at 305.66, while, T3 treatment showed the lowest firmness values 130.00 during cold storage. Firmness values were changed over the period of cold storage. It decreased as the progress of storage period up to 14 days in all yogurt treatments.

Adhesiveness is the required force to eliminate the material that adheres to the mouth throughout eating (Ganesh, 2006). Our results showed that the values of adhesiveness (g.s) evaluated in plain yogurt (C) and yogurt fortified with Kiwi pulp during storage (Figure 2G). The values among the samples were significantly different (p<0.01). These adhesiveness values were lower in the T3 samples than all treatments in other fortified yogurt or control yogurt. T1 samples recorded the highest adhesiveness values in comparison with other yogurt treatments. It is clear that throughout the storage period, adhesiveness values were increased in all treatments. T1 fortified yogurt has the highest value whereas T3 was the lowest.

Consistency or the flow ability in that mesh probe compresses the yogurt sample over a specified distance (Prajapati *et al.*, 2016). Consistency values of the yogurt samples which have a great impact on the yogurt tenacity, were evaluated at fresh samples and throughout the storage period (Figure 2H, I). The data illustrated the differences among yogurt treatments as a result of the addition of Kiwi pulp. There were significant differences between all fortified and plain yogurt (p<0.01). Yogurt fortified with 5% Kiwi pulp T1 had the highest consistency values which were 846.66 and 917.33. In contrast, T3 fortified yogurt with 15% Kiwi pulp has the lowest values 137.33 and 187.80 at zero time and after 14 days of storage respectively. With the progress of the storage period consistency values tend to increase in all fortified yogurt treatments.

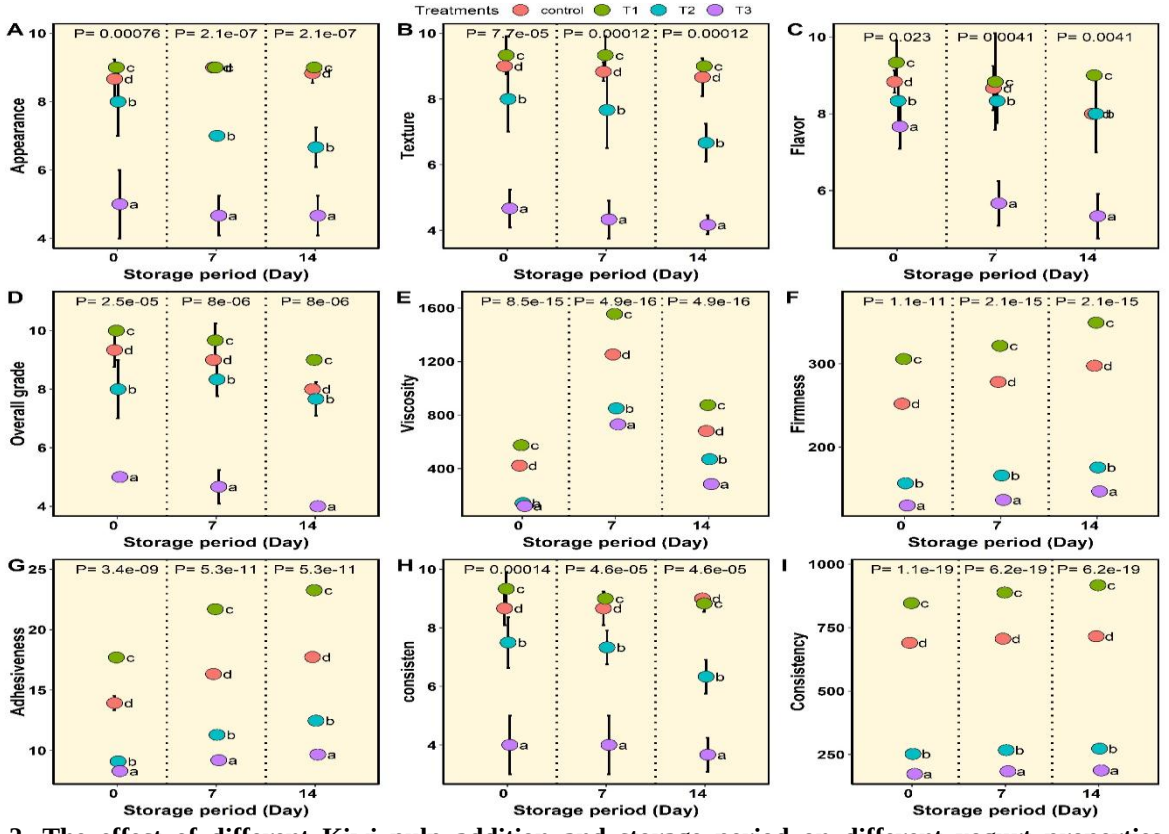


Fig. 2. The effect of different Kiwi pulp addition and storage period on different yogurt properties. (A) Appearance, (B) Texture, (C) Flavors, (D) Overall grade, (E) Viscosity (F) Firmness, (G) Adhesiveness (H) consisten values, (I) and Consistency values. Values represent the mean ± standard deviation (means ± SD) of three biological replicates (n= 3). Different letters indicate statistically significant differences between treatments (p<0.05)

Sensory evaluation of fortified yogurt:

The results of sensory evaluation revealed that the sensory parameters including appearance, texture, consistency, flavor, and the overall grade of yogurt treatments have significant differences (p<0.01) during the storage period (Figure 2 A-D). The sensory scores increased with supplemented yogurt with Kiwi pulp treatments except T3 fortified yogurt (15% Kiwi pulp) which has minimized appearance, flavor, texture, and consistency and overall grade scores at the starting day even after the storage period. Interestingly, all yogurt treatments were accepted by judges. By prolonging of storage period (T1) and T2 have high scores of sensory evaluations 10 and 8 overall grades compared with (T3).

The simple linear regression (SLR) of yogurt analysis:

The simple linear regression (SLR) as presented in Figure (3A) was used for a better understanding of the relationship between TS content and the storage period of control and fortified yogurt samples. Results illustrated that the relationship between TS and storage period was positively correlated. As the storage period progressed, the TS content of yogurt increased as; (C) and (T1) have a strong positive correlation:

$$C\ y=0.029x+14,\ T1\ y=\ =0.018x+15.$$

While there was a positive relationship between T2 and T3 for T2 y=0.019x+13, T3 y=0.015x+12.

The results in Figure (3B) showed the relationship between fat content and storage period using linear regression (SLR). There was both a strong and weak positive correlation between yogurt fat content and storage period progress. The weak positive correlation exhibited in T1 fortified by 10%Kiwi pulp; T1 y=0.0038x+3.40. This observation was confirmed by SLR where the relationship between protein content and storage period is shown in Figure (3C). It demonstrated that protein content and storage period had a strong positive correlation in all yogurt treatments while in treatment the correlation was weak positive as evidenced by the equipment T2 y=0.006x+3.1.

For more understanding of the relationship between ash content and the storage period, the SLR was used as revealed in Figure (3D). The results clarified that there is a high correlation between ash content and the progression of the storage period in all yogurt treatments. As it observed in equations; T2 y =0.00048x+ 0.99; T3 y= 0.00048x+ 0.99. The relationship between carbohydrate content and storage period was demonstrated by SLR as shown in Figure (3E). A positive correlation was noticed in all yogurt treatments, with high correlation values with C and T1 yogurt as shown in equation C y=0.017x+5.9, T1 y= 0.0097x+6.7 while, T3 has a low positive correlation T3 y= 0.0052x+5.4.

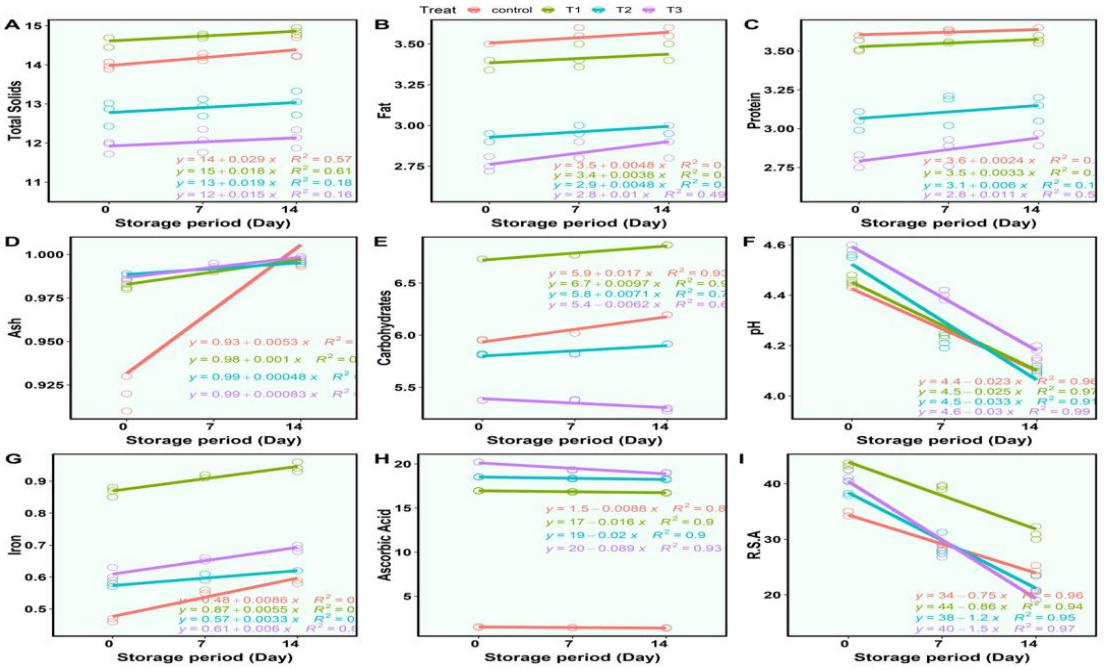


Fig.3 . The simple linear regression (SLR) between storage period and effect of different Kiwi pulp addition on physiochemical properties of yogurt. (A) total solid content, (B) fat%, (C) protein %, (D) Ash content, (E) Carbohydrates content (F) Appearance, (G)m Texture, (H) Flavor, and (I) Overall grade

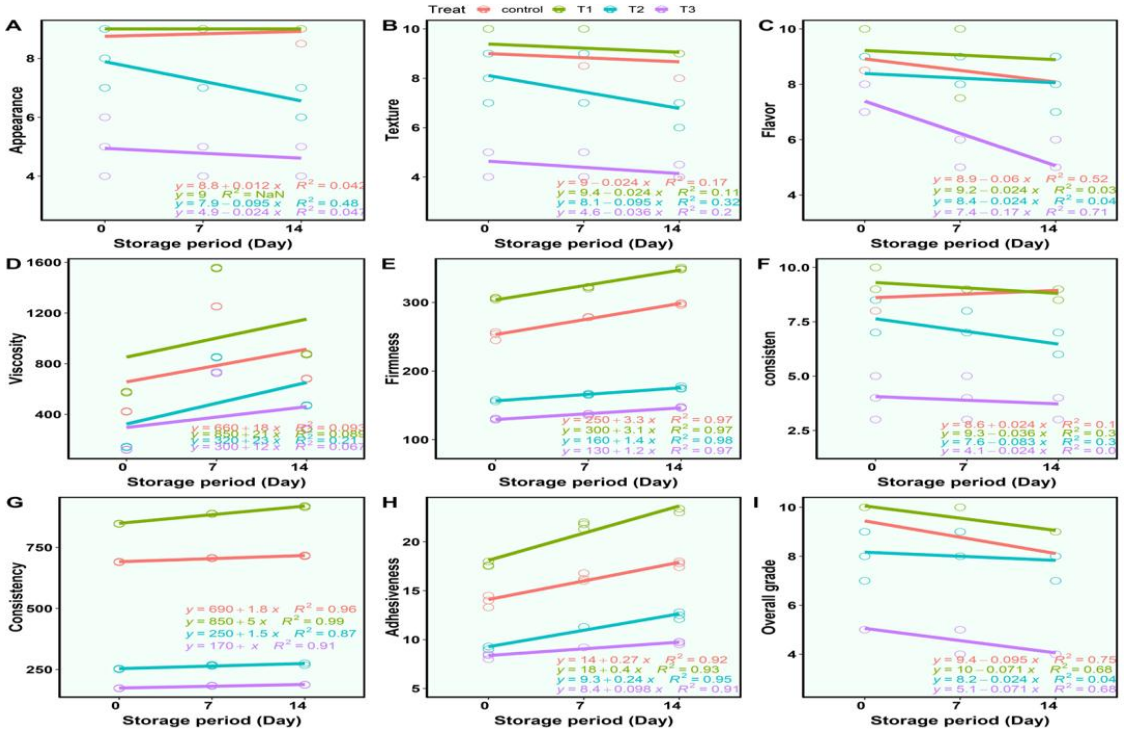


Fig.4. The simple linear regression (SLR) between storage period and effect of different Kiwi pulp addition on physiochemical properties of yogurt. (A) pH, (B) Viscosity, (C) Firmness, (D) Adhesiveness, (E) Consistency, (G) Iron, (H) Ascorbic acid, and (I) R.S.A.

The results in Figures (3F-I) showed the relationship between the sensory properties of yogurt treatments and the storage period. There was a weak positive correlation between appearance, texture, flavor, and overall grade with the progress of the storage period in all yogurt treatments. However, there was a strong correlation between overall grade and storage period. It was observed with T2; T3 treatment T2 y= 0.071x+5.1.

On the other hand, Figure (4A) illustrates the results of SLR which indicated that there is a strong positive correlation between the pH values of yogurt treatments and the storage period as shown with T3 yogurt T3 y=0.03x+6.06. The results in Figure (4B) showed the relationship between the viscosity of yogurt treatments and the storage period. There was a weak positive correlation between viscosity values and the progress of the storage period in all yogurt treatments. T3 fortified yogurt has the lowest positive correlation however, T2 has the highest. According to the results of SLR in Figure (4C), all fortified samples have a strong positive correlation between firmness and the period of storage as shown in these equations:

C y = 3.3x + 250; T1 y = 3.1x +300; T2 y = 1.4x + 160; T3 y = 1.2x +130.

Figure (4D) illustrates the results of SLR to understand more about the relationship between the adhesiveness of yogurt treatments and the progress storage period. There was a strong positive correlation between adhesiveness and storage period. This was more noticeable in T2, y=0.24x+9.3. As shown in Figure (4E), a strong positive correlation between the consistency and the progress storage period was observed in all yogurt treatments particularly in T1 yogurt with a high positive correlation as shown in equation T1 y=5x+850, while T3 has a weak positive correlation, T3 y=1x+170.

SLR exhibited the relationship between iron content and storage period of control and fortified yogurt as shown in Figure (4G). Iron content positively correlated with storage period. Moreover, iron content increased throughout the storage period for all yogurt treatments. During the prolonged storage period, the ascorbic acid content of yogurt decreased in all treatments as shown in Figure (4H). Results of SLR illustrated that there was a positive correlation between antioxidant activity or R.S.A of yogurt treatments and the storage period (Figure 4I). Control yogurt exhibited the lowest positive correlation, while yogurt fortified with 15% T3 has the highest correlation as shown in the equations, C y=0.008x+1.5; T3 y=0.089x+20.

The principal component analysis and correlation analysis:

Principal component analysis (PCA) was conducted including all obtained data from all yogurt treatments to investigate the effect of Kiwi pulp addition on the physio-chemical and sensory properties of yogurt. As shown in Figure (5A and B), the first (PC1), the second (PC2), and the third components (PC3) have the major impact in the separation of the groups with the highest scores of 67.6%, 14.4%, and 8.6% respectively, among 10 components of the data matrix. However, PC1 and PC3 perfectly illustrated the variance and distribution between Kiwi-supplemented groups and the negative control group (Figure 5B). The clusters of T1, T2, and T3 separated from the control cluster which reflected the significant differences in the features and properties of yogurt after adding Kiwipulp. While clusters of T2 and T3 were separated by PC1 from the clusters of Control and T1 groups. Interestingly, a cluster of T3 was the furthest one from the control group confirming that by increasing Kiwipulppercentage, the yogurt has considerable divergent characteristics compared to the plain samples proving the efficacy of Kiwi pulp addition. Meanwhile, these results support the previous observation of quantitative and qualitative properties of yogurt that are shown in Figures (1 to 4). According to Figure (5C), the main variables that attributed to this separation among groups are Iron, total solid, firmness, consistency, adhesiveness, flavor, viscosity, and pH. Furthermore, correlation analysis was performed to investigate the relationships among characteristics of the yogurt under different treatments (Figure 5D). Iron content was highly correlated with total solids, adhesiveness, firmness, and consistency (R=1) confirming that Iron has a huge impact on these parameters and can be a good parameter to improve these properties in yogurt. However, there is a significant correlation between fat, protein TS and texture, appearance and firmness, and consistency (R 0.8-1). On the other hand, pH exhibited a positive relationship to RSA, but negatively corresponded to protein, fat, and TS contents of the yogurt. According to these results of PCA, supplementation of Kiwi pulp has positive effects on yogurt not only increasing its nutritional value but also enhancing its sensory, chemical, and physical properties.

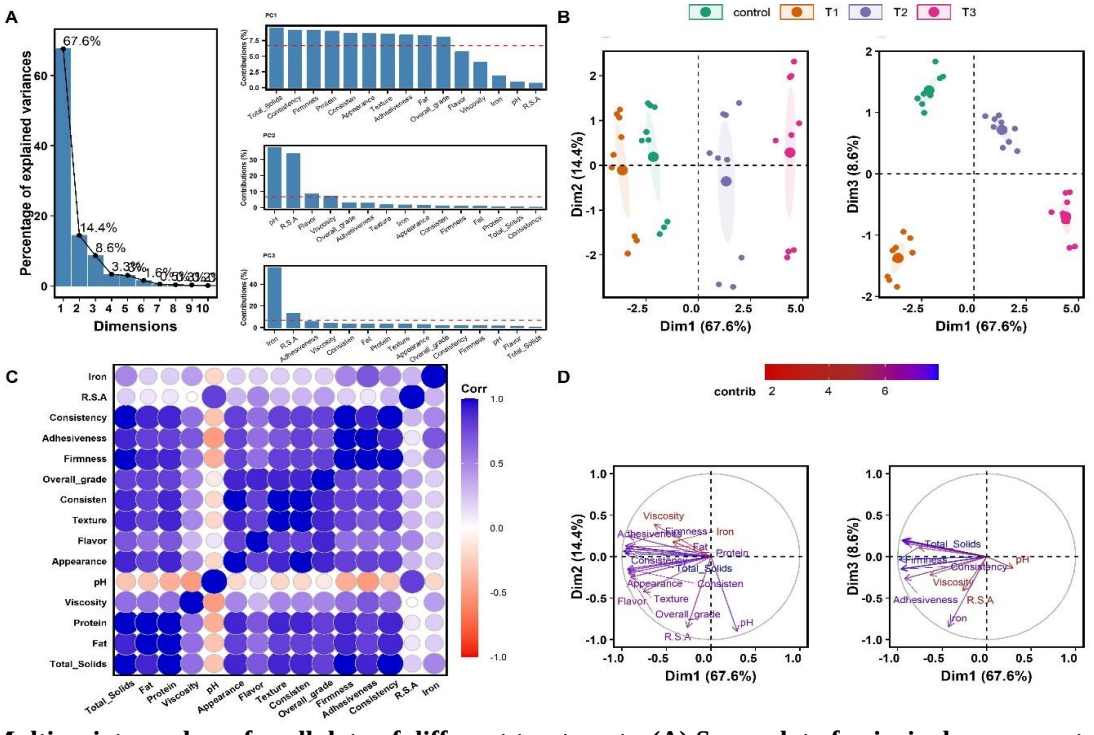


Fig.5 .Multivariate analyses for all data of different treatments. (A) Scree plot of principal component analysis (PCA) (B) Score plot of PCA (The first component 67.6% and the second component 14.4%, and the third component 8.6%). (C) Correlation analysis. D) Loading plot of top variables contributed to PCA.

Kiwi fruit is commonly acknowledged to possess significant nutritional value, exhibiting a notable abundance of vitamin C as observed in fortified yogurt treatments compared with control samples (Richardson *et al.,* 2018). They also have a significant amount of fruit sugars, much like most mature fruit (Drummond, 2013). Kiwi fruit, known to be a challenge in managing blood glucose levels, can contribute to glycemic control when consumed as part of a carefully managed carbohydrate intake (Mishra *et al.,* 2016). The quantity of carbohydrates that is present in Kiwi fruit is approximately 50% fructose. This particular type of carbohydrate possesses a low glycemic index (GI) (Foster-Powell *et al.,* 2002). The potential outcome of this is a considerable decrease in the impact on blood sugar levels that can significantly enhance the nutrient content of the diet without causing a major impact on carbohydrate intake, glycemic response, or insulin levels (Monro *et al.,* 2018). Another point to consider is that there are other elements present in Kiwi fruit, aside from sugars, which contribute to the anti-glycemic effect (Mishra *et al.,* 2017).

Decreased pH values of fortified yogurt compared to the control sample may be due to Kiwi fruit having organic acids, such as Quinic acid, Tetradecanoic acid, and Hexadecanoic acid which are quantitatively important components of Kiwi fruit, This can potentially hinder the digestion of starchy foods in the stomach by reducing the pH, which affects the activity of salivary amylase (Freitas & Le Feunteun, 2018 and Freitas *et al.,* 2021). They may also delay the release of gastric chyme to the duodenum (Liljeberg and Björck, 1996), as the exceptionally strong buffering capacity of Kiwi fruit organic acids (Mishra *et al.,* 2017). Extended gastric production of HCl is necessary to lower the pH to the desired level. Additionally, the presence of highly buffered chyme with low pH in the duodenum triggers the intragastric reflex, causing a delay in gastric emptying (Hunt and Knox, 1969). These components of Kiwi fruit may be responsible for the lowering of glycemic impact.

Kiwi fruit contains different benefit compounds such as Dihydroxyacetone (1,3-dihydroxy-2-propanone, DHA. DHA is classified as ketotrioses. It is widely used as a fragrance enhancer for thermally-processed products (Erni *et al.,* 2006), and as an intermediate for the production of anticancer drugs (Gätgens *et al.,* 2007). DHA is also used in the production of polyethylene glycol, which is a component of antiperspirants, toothpaste, and hand hygiene products (Stasiak-Różańska and Błażejak, 2012). Quinic acid contributes to the flavor, sugar balance,and health-giving properties of the product, Tetradecanoic acid and n-Hexadecanoic acid were found in Kiwi fruit extract that helps to improve the functional features of fortified yogurt. the positive effects on human health could protect the body against different diseases such as diabetes, aging, hypertension, and cardiovascular (Singh *et al.,* 2023). They also protect against the oxidation of LDL cholesterol and other lipids in the blood (Sun-Waterhouse *et al.,* 2013).

Fermented products like yogurt are considered synthesized foods manufactured via the fermentation process of milk which occurs by using starter culture bacteria. Yogurt is the most fermented product widespread with higher comparatively consumption as well as several benefits for human health (Corrêa *et al.,* 2018). Commonly yogurt is processed by the traditional method unless several researchers have modified the technologies and procedures of manufacturers. Likewise, the supplementation and fortification of yogurt with other food products and nutrient ingredients.This process helps enhance yogurt quality and promote its sensory properties which is known as a fortification (Ahmad *et al.,* 2022).

The properties of yogurt are influenced by various factors likewise, the milk type, starter culture bacteria, and the ingredients added in various concentrations to reinforce the quality as well as rheological properties and raise the nutrient value (Ahmed *et al.,* 2023). In the current study, fortified yogurt with natural fruit additives likewise Kiwi fruit promotes its physicochemical, textural, sensorial, and rheological features. Additionally, throughout the cold storage of yogurts, the triple helices of fermented gelatin at bound points strengthen gelation and lessen whey mislaying through syneresis which leads to promoting the yogurt viscosity (Mudgil *et al.,* 2018). Fortification of yogurt by Kiwi fruit enhances the health benefits and chemical composition of fortified yogurt and reinforces its organoleptic characteristics, as well as color, texture features, as well sensory properties (Su *et al.,* 2018). The same observation in the current study where yogurt treatments fortified with 5 and 10% Kiwi pulp (T1 and T2) showed significant changes in these parameters compared to plain yogurt.

Texture parameters of Kiwi pulp fortified yogurt treatments were different from those of control yogurt such as firmness which was higher in fortified yogurt than control. Additionally, the firmness or hardness of the yogurt and other fermented products depends on several factors such as bacterial culture composition. These bacteria improve the firmness of the yogurt via produced metabolic products, and protein content of the product, as well as the type of protein and the interplay among the other ingredients that are used during the

manufacturing (Mishra *et al.,* 2016). Similarly in our results where the consistency values of fortified yogurt were significantly high ($p<0.01$) compared with control yogurt such as values of T1 fortified with 5% of Kiwi pulp 846.66. This could be related to the interactions between whey proteins and κ-casein making the micelles less sensitive to the pH decline, increasing their solubility which effects on consistency value (Costa *et al.,* 2015). Fortification yogurt by Kiwi fruit impacts texture parameters, such as firmness and adhesiveness (Oliveira *et al.,* 2001 and Shihata & Shah, 2002). The characteristics of fortified yogurt with Kiwi fruit were different from control yogurt. As the rate of fortification increases the characteristics of yogurt exchange such as in viscosity value. T2 and T3 had the lowest viscosity values compared with T1. This may be due to the acid properties of Kiwi fruit which led to increased fermentation of lactose and a decline in the viscosity (Tarakci, 2010).

Additionally, fortification of yogurt with Kiwi fruit may affect the state of acid production of yogurt, due to the polyphenols and other substances in fortified treatments. These components could raise the fermentation of lactose which raises the lactic acid production, likewise, this expands the biomass as well as boosts lactic acid bacteria. In contrast, this has an impact on pH values and is relatively with the quality characteristics and self-life of fortified products (Zhang *et al.,* 2016). According to our results, fortified yogurt by Kiwi fruit has different properties compared with control yogurt due to several action mechanisms that occurred due to Kiwi pulp fiber content and the presence of actinidin enzyme that had a natural proteolytic activity. As the level of Kiwi fruit in fortified yogurt by more than 5% the actinidin enzyme broke down the protein (Boland, 2013). In contrast, this result led to improved digestion by facilitating gastric as well as producing other phytochemicals that could encourage motility (Ciardiello *et al.,* 2008).

Utilization of Kiwi fruit in the fortification of yogurt enhances its quality features as Kiwi fruit has a high amount of functional ingredients such as vitamin C and other functional components likewise, 2-Deoxy-D-galactose and 2-Propanone, 1,3-dihydroxy-) that enhanced the flavor and acceptability. Our results indicated that Kiwi pulp supplementation increased sensory evaluation of produced yogurt (Figure 4) (Nishiyama *et al.,* 2005). Fortification yogurt Kiwi fruit as a functional ingredient is considered a convenient choice to increase health benefits due to increasing radical scavenging activity and subsequently enhancing the self-life of the fortified product (Su *et al.,* 2018). Similarly in our results where Kiwi-fortified yogurt exhibited high RSA compared to plain yogurt (Figure 2E, F). Consumption of fortified products with Kiwi fruit promotes human health which may be attributed to its dietary fiber content. Also, Kiwi pulp supplementation reinforces the intestinal beatifical microflora community and enhances metabolism and protein digestion via its natural proteolytic enzyme actinidin which in turn improves the immune system (Richardson *et al.,* 2018).

Generally, the organoleptic or sensory characteristics of yogurt are one of the vital features of fermented products that have a remarkable role in the evaluation of the quality of yogurt. It defends metabolites produced by starter cultures bacteria that provide compotation of flavor components via produced various compounds such as lactic acid as well carbonyl compounds acetaldehyde and diacetyl (Gallardo-Escamilla *et al.,* 2005). Furthermore, lactic acid affects yogurt taste as well as affects the consumer's acceptability. The flavor of yogurt is constructed by different reactions including chemical and enzymatic reactions, fermentation of carbohydrates, lipolysis as well as proteolysis and amino acids catabolism (Ott *et al.,* 2000). Fortified yogurt with Kiwi fruit increased flavor scores of fortified yogurts compared to plain samples (Figure 4). That may be due to the flavor components in Kiwi fruits (Jordán *et al.,* 2002). Furthermore, Kiwi fruit has a high content of ascorbic acid and low content of tannin which helps the interaction between Kiwi pulp and yogurt resulting in indifferent senses and enhanced flavor quality that can be affected by lipid oxidation and degradation during the storage period (Ames and Macleod, 1984).

The volatile organic compounds (VOCs) in the Kiwi fruit extract may be behind the taste and flavor of the fortified yogurt including 8.674% ketones such as (2-Propanone, 1,3-dihydroxy-, 2,5-Furandione, 3-methyl-). Also, it had Alcohols 43.391% such as Pentanoic acid. As well as it contains 14.563% acids (Quinic acid. There are also, aldehydes likewise, Benzaldehyde. Additionally, 5.365% other compounds as (2-Deoxy-D-galactose and d-Glycero-d-galacto-heptose). These substances enhance the health benefits and increase the nutritional value as well as affect the aroma of the fortified yogurt compared with plain one. Finally, VOCs play an effective role in tracing the yogurt production and acceptability of product (Garcia *et al.,* 2012).

CONCLUSION

Fortified yogurt with Kiwi pulp could be a promising production of functional dairy food. Kiwi fruit incorporated yogurt enhanced the physio-chemical properties such as TS and protein content of Kiwi fruit yogurt which in turn increases its benefits from the health and nutrition point of view. Moreover, fortification of yogurt with Kiwi pulp enhances antioxidant activity and overall acceptability of the

fortified yogurt. Additionally, fortified yogurt with 5% Kiwi pulp exhibited the possibility of producing yogurt with high-quality characteristics at zero time up to 14 days of cold storage period. Permission, Kiwi pulp fortification represents a promising functional additive in yogurt manufacturing to produce fortified yogurt with high nutritional values and health benefits.

AUTHOR CONTRIBUTIONS

This work has been done by all authors

DATA AVAILABILITY STATEMENT

Data is contained within the article.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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الملخص العربي

تعزيز القيمة الغذائية والخواص الوظيفية للزبادي المدعم بلب الكيوي

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الزبادي هو منتج متخمر معروف عالميًا. كما أنه يُستخدم كغذاء مغذي نظرًا لقيمته الغذائية وتحسينه لخواص هضم الحليب. تُعد فاكهة الكيوي من أكثر الفواكه الصحية في العالم نظرًا لمحتواها العالي من الألياف الغذائية ومركبات مضادات الأكسدة التي تعزز جهاز المناعة وتعزز صحة الأمعاء. لذلك، هدفت هذه الدراسة إلى دراسة تأثير إضافة نسب مختلفة من لب الكيوي على الخصائص الفيزيائية والكيميائية والحسية ونشاط مضادات الأكسدة للزبادي المعامل طوال فترة التخزين البارد لمدة ١٤ يومًا. تم تصنيع ثلاث معاملات زبادي من حليب البقر المبستر T1, T2, T3 مدعم بلب الكيوي بنسب ٥%، ١٠%، ١٥% على التوالي، عينة زبادي (C)بدون إضافات كعينة مقارنة. أظهرت النتائج أن الزبادي المدعم بلب الكيوي كان له اختلافات كبيرة مقارنة بالزبادي الخام. سجّلت T1 أعلى القيم في تحليل الخواص الفيزيائية والكيميائية، واللزوجة، القوام. علاوة على ذلك، أظهر كلٌّ من T1و T2 قبولاً عامًا عاليًا للخواص الحسية. ومن المثير للاهتمام، وجود زيادة ملحوظة في نشاط مضادات الأكسدة ومحتوى الحديد في الزبادي المدعم بلب الكيوي. وبالتالي، فإن إضافة فاكهة الكيوي لم تُحسّن الخواص الفيزيائية والكيميائية والحسية للزبادي فحسب، بل حسّنت أيضًا قيمته الغذائية.

الكلمات المفتاحية: الزبادي؛ فاكهة الكيوي؛ مضادات الأكسدة؛ الخواص الفيزيائية والكيميائية والحسية.