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Manufacturing Functional Yogurt Enriched with Rhamnus Alaternus Fruit Powder and Studying Some of its Properties

Nahla Tariq Khalid[1]*, Firas Ahmed Salih[2], Jaafar Nozad Aakef AAKEF[3]

Department of Food Sciences, College of Agricultural Engineering Sciences, University of Baghdad, Baghdad, Iraq
nahla.tariq@coagri.uobaghdad.edu.iq ORCID: 0000-0002-6566-0152
Firas.A.520@coagri.uobaghdad.edu.iq ORCID: 0009-0006-4496-3070
jaafar.n@coagri.uobaghdad.edu.iq ORCID: 0000-0002-2156-2868
*Corresponding Author: Nahla Tariq Khalid
Email: nahla.tariq@coagri.uobaghdad.edu.iq

ABSTRACT: Functional yogurts enriched with plant-based bioactive compounds have emerged as promising dietary strategies to enhance human health.

Objective: This study investigated the fortification of yogurt with Rhamnus alaternus fruit powder and its impact on quality characteristics, sensory attributes, and antioxidant activity.

Methods: The current study involved preparing a powder from the fruit of the R. alternus plant, which underwent chemical and antioxidant analysis. was chemically analyzed including protein, fat, ash, moisture and fibers, and the percentage of minerals Ca, Fe, Mg and Pb in the powder was estimated using GC-Mass device. The antioxidant activity of R. alternus powder was tested against (DPPH). Fresh buffalo milk was used to prepare yogurt, were fortified with the R. alternus powder, sensory evaluation of these fortified products was then conducted.

Results: The chemical composition of R.alaternus fruit powder revealed that moisture was the highest component (28.45%), followed by fat (7.60%), crude fiber (3.98%), ash (3.95%), and protein (1.53%). The DPPH radical scavenging activity was 63.28%, indicating notable antioxidant potential. Mineral analysis showed calcium (19.35 ppm) and magnesium (10.50 ppm) as the dominant elements, while iron (0.20 ppm) and lead (0.37 ppm) were present in lower concentrations. Among the tested methods, 70% aqueous ethanol produced the highest extract yield, particularly with cold maceration (30.15 g/100 g). Sensory evaluation of yogurt supplemented with R. alternus powder demonstrated significant improvements in taste (6.40 vs. 5.30), flavor (7.30 vs. 6.64), texture (5.60 vs. 5.23), color (7.00 vs. 6.54), and overall acceptability (7.50 vs. 7.12) compared to the control ($p < 0.05$).

Conclusion: R. alaternus fruit powder demonstrated promising nutritional and antioxidant properties and significantly enhanced the sensory quality of fortified yogurt. These findings support its potential application as a natural functional ingredient in dairy product development.

INTRODUCTION

Yogurt is a commonly consumed, fermented dairy product obtained from metabolic action of *Lactobacillus delbrueckii subsp. bulgaricus* and *Streptococcus thermophilus*. It is an important nutritional food as its high macro- and micronutrients content includes essential nutrients. Furthermore, yogurt is considered a key element for maintaining energy ratio in daily diet[1] Various commercially available varieties of yogurt exist and they are widely accepted because of their favorable sensory attributes and convenience[2]. Despite having beneficial nutrients and known health benefits, plain yogurt has few phenolic compounds, making it an ineffective source of dietary antioxidants. Diverse phenolic compounds have been detected in ruminant milk including carvacrol, thymol, phenol and cresol and their relative abundance varies depending on the mammalian species [3]. Sheep milk was reported to contain the highest total phenolic content among types of milk, with approximately 168 mg GAE/L, but higher levels were not found in cow milk [4]. The differences in the phenolic profiles between species are primarily related to the feeding regimes and chemical composition of ruminant diets. Because of such variability and the need to assess improve dairy product nutrition efficiency, fruit-derived additives are widely integrated into yogurt formulations as natural fortifying ingredients [5].

Rhamnus alaternus L., a Mediterranean-affiliated plant belonging to the Rhamnaceae family, is a shrub or small tree native to the Mediterranean region, total polyphenol content and has the highest percentage of free polyphenols compared to other fruits, therefore, it is used traditionally for medicinal and nutritional purposes. known as dogwood or Gesho in Amharic, is widely distributed in many countries of eastern, central, and southern Africa[6], its various parts fruits, leaves and bark have been historically employed in traditional medicine to treat gastrointestinal disorders, hypertension, dermatological issues and digestive complaints. These are traditional claims that have been validated in the last few decades by scientific studies that show *R. alaternus* has a wide range of bioactive compounds, especially polyphenols and flavonoids, which correlate highly with antioxidant, antibacterial and antimutagenic activities[7], Also, these compounds have shown promise in various pharmacological applications, such as anti-mutagenic, anti-hyperlipidemic, and antimicrobial activities owing to its richness in phytochemical compounds belonging to different families like anthraquinones, flavonoids, and anthocyanins, some of these molecules were isolated from *R. alaternus* using different extraction processes (i.e., maceration, boiling, hydrodistillation, Soxhlet, ultrasonic extraction) [8]. It has shown various pharmacological properties including anti-hyperlipidemia, antioxidant, antitoxic, antiproliferative, and anti-mutagenic activities[9].

These characteristics have made the *R. alaternus* fruit powder a potential functional food supplement and ingredient. Functional yogurts enriched by plant powders containing phenolic compounds have been widely investigated[10]. Many studies have demonstrated that the addition of fruit and plant powders increases yogurts antioxidant profile while providing the sensorial proprieties, e.g., color, aroma, and texture. For instance, in relation to the yogurt fortified with citrus fruit peel showed a rise that was higher than plain yogurt in total phenolic content and antioxidant capacity, showing that addition of bioactive plant ingredients significantly increase functional characteristics[11]. The objective of the current study was to investigate the potential use of *R. alaternus* fruit powder as a natural functional ingredient in the fortification of yogurt, the study was focused on its chemical composition, mineral content and antioxidant activity as well as its impact on qualitative characteristics and sensory properties of the fortified yogurt in comparison with control sample.

MATERIALS AND METHODS

The present study was carried out in the microbiology and physicochemical laboratories of the Department of Food Sciences - College of Agricultural Engineering Sciences - University of Baghdad, Baghdad, Iraq. Fresh caw milk was sourced from the university's dairy farm.

Collection, Identification and Preparation of Plant Material

Fresh fruits of *Rhamnus spp.* were obtained from a local market and subsequently submitted for botanical identification to confirm their taxonomic classification. The collected fruits were cleaned and air-dried under shade conditions, followed by additional sun-drying for three days to ensure complete moisture removal. After drying, the fruits were finely ground into powder form and preserved in sterile glass containers at room temperature until further experimental use.

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Plants Extraction

The plant material had been subjected for three types of extraction method; maceration with 70%Ethanol, indirect hot continues method by soxhlet apparatus with 70% ethanol, and digestion method for aqueous extraction with distilled water[12].

Cold Ethanolic Extraction

About 100g plant material was macerated with 700 ml of 70%Ethanol for 5 days in sealed container in a dark cool place with alternative shaking. The extract of the plants was filtrated through Whatman No. 1, concentrated at 45 C^0 by rotary evaporator, then each residue was weighted and kept in dry clean containers at 4 C^0 till used [13].

Indirect Hot Continuous Ethanolic Extraction with Soxhlet

The second portion of the chopped plant material (50) g was subjected to indirect heat extraction method using Soxhlet apparatus for 8 hours with 600 ml methanol 70%. The solvent had been dried then with rotary evaporator at 45^0 C. and the residue from this extraction method was weighted and kept in sealed dried container [14].

Cold Aqueous Extraction

About 100g from powdered dried plant was extracted with distilled water through digestion method using magnetic stirrer at 60^0C for 2 hours then cooled and filtered. The filtrated was send for drying by lyophilized apparatus[15]. In all methods the weight percentage for each yield residue was calculated in equation 1 according to [16]

$$\%\,Yield = \frac{Weigth\ of\ dry\ extract}{Weigth\ of\ sample} \times 100$$

Preliminary phytochemical screening for the three fractions of the plant extract

From the residue of extracted yields 100 mg was re-dissolved in 10 ml distilled water separately was subjected to general phytochemical screening tests to check the absence or presence of different secondary metabolites such as Saponin, tannins, polyphenols, flavonoids, alkaloids, and reducing sugars in the plant extract [17].

Methods of Analysis

Ash, fiber content, and fat of samples were determined according to the AOAC (2008)[18], protein was determined by Kjeldahl method as mentioned by (AOAC, 2000)[19], moisture determine according to [20], the pH value was measured by using a digital pH meter (M4 1150 USA) equipped with glass electrode[18].

Preparation of Yoghurt

The yoghurt was prepared with powdered dried plant along with a control. The caw milk was standardized at 11% solids non-fat and 4% fat content. Milk was homogenized and pasteurized at 85 °C for half hour [21].

Preparation of yogurt

Yogurt was prepared according to the method described by Ahmad *et al.* [1] with slight modification. Briefly, The caw milk was standardized at 11% solids non-fat and 4% fat content. Milk was homogenized and pasteurized at 85 °C for half hour [21]. Finally, the milk was returned to 45 °C and mixed with an addition of a total of 12 g yogurt starter culture. Next, 12.5 g (5%) of *Rhamnus* powdered dried was incorporated into the mixture and blended uniformly. Incubation was carried out at 45°C for 3 h until solidification. The pure prepared yogurt samples were kept in low temperature storage before proceeding for further evaluations

Sensory evaluation

The sensory characteristics (bitterness, flavor, color, appearance, texture, and overall acceptability) of samples were evaluated by an evaluation panel of faculty members from the Dairy acceptance by qualified professors specialized in the Department of Food Sciences - College of Agricultural Engineering Sciences - University of Baghdad. All had experience of standardized tests for olfactory and taste sensitivities as well as verbal abilities and creativity. They evaluated 30 g portions of each yoghurt sample and used a quality rating score card for evaluation of bitterness (nine points), flavor (nine points), color (nine points), appearance (nine points) , texture (nine points) and overall acceptability (nine points) as described by [22].

Estimation of mineral elements

The mineral elements were estimated by the GC-mass device and the AOAC (2008) method was followed, where they were digested and estimated by the device. A weight of 0.5 g of the sample was taken, then 5 ml of HNO_3, 1 ml of H_2SO_4, and 1 ml of $HCLO_4$ were added to it, then it was placed on a hot surface and waited until the acid evaporated, the sample was filtered, then it was placed in a volumetric flask and the sample was completed with distilled water to the required volume, and a specific volume was taken and estimated by the GC-mass device.

DPPH radical scavenging assay

Antioxidant activities for aqueous and ethanolic extract from *Rhamnus* and ascorbic acid were calculated using the DPPH assay with some adjustments, as conducted by Abdulkareem *et al.*[23]. An aliquot of 1 mL of *Rhamnus* extract solution prepared in ethanol at concentrations of 15.1, 31.2, 62.5, 125, 250, 400, and 500 µg/mL was mixed with an equal volume of DPPH solution. The mixture was incubated for 1 hour in the dark at room temperature, after which the absorbance was measured at 517 nm using a UV–Vis spectrophotometer (Shimadzu 1800, Japan). All measurements were carried out in triplicate (n = 3). The DPPH radical scavenging activity of the sample was calculated using the following equation [24].

$$\textbf{DPPH scavenge effect } (\%) = \frac{\textbf{A control} - \textbf{A sample}}{\textbf{A control}} \times \textbf{100} \qquad (\textbf{1})..$$

Statistical analysis

Data statistically analyzed using Statistical Analysis System (SAS), version 2018 to evaluate the effects of treatments on studied parameters based on completely randomized design (CRD). The Least Significant Difference (LSD) test was used to compare for differences between treatment averages at statistical significance.

3. RESULTS AND DISCUSSION

Chemical Composition

Table (1) shows the chemical composition of *Rhamnus* powder sample. The moisture content was the largest among the components measured, accounting for 28.45%. The fat value was 7.60%, at the second in very close values) crude fiber of 3.98% and ash content (3.95%) were recorded. The protein level was the only measured nutritional component that scored 1.53% of total composition (the lowest). The DPPH radical scavenging activity of *Rhamnus* powder sample was found to be 63.28%.

Table 1. Chemical composition of the *Rhamnus* powder sample.

Component	%
Protein	1.53
Fat	7.60
Ash	3.95
Moisture	28.45
Fibers	3.98
DPPH	63.28

This prevalence in moisture is consistent with reports on the fruits of *R. alaternus*, described to contain relatively high water contents attributable to their fleshy pericarp structure. Accompanied by moisture (the predominant fraction), composition patterns from Mediterranean wild fruit have been described, influencing texture, shelf stability and tendency to microbial spoilage[25]. *Rhamnus* fruits have found to contain significant amounts of both fatty acids and lipophilic bioactive compoundsb which is in line with previously described moderate fat percentage presented herein[26]. There have been studies that investigated the nutritional profile of *R. alaternus* fruits which reported detectable lipid levels that contribute to energy value and possible functional properties[27]. the obtained cut out crude fiber content (3.98%) was above a levele're achieved by finding of previous characterizing studies which revealed that wild berries are abundant in structural carbohydrates such as cellulose and hemicellulose promoting dietary fiber intake and gastrointestinal health [26]. The ash content (3.95%) indicates the mineral constituents present, which is consistent with previous compositional studies of Mediterranean shrubs that report a high concentration of minerals in fruits [28]. On the other hand, the low protein content (1.53%) is also in accordance with fruit composition trends in general since legumes or cereals are poor in this nutrient and have higher contents[29].

Comparable investigations on several *Rhamnus* species have demonstrated variable antioxidant capacities when evaluated using DPPH assays. Extracts derived from the of *Rhamnus alaternus, Rhamnus fallax, Rhamnus intermedia*, and *Rhamnus pumila* exhibited measurable radical scavenging activities with EC_{50} values reported within different ranges, indicating interspecific variability in antioxidant strength[6, 30]. Similarly, extracts of *Rhamnus catharticus* and *Rhamnus orbiculatus* demonstrated effective scavenging concentrations in the microgram per milliliter range. These interspecific differences are generally ascribed to differences in total phenolic content (TPC) and total flavonoid content (TFC), classes which are known to be the main factors of antioxidant activity in plant extracts. Phytochemical studies indicate strong correlations between phenolic levels and radical scavenging activities [31]. Due to their capability of donating hydrogen atoms or electrons to free radicals which are unstable and hence lead into a oxidative chain reaction, phenolic compounds can serve as efficient donor of hydrogen atom: decomposing the unstable radical and controlling oxidation. Based on the observation made in this study, that bioactive compounds may be responsible for the observed antioxidant property[32].

Antioxidant activity evaluated by DPPH assay depends on the reduction of stable free radicals. Polyphenols possess hydroxyl (-OH) groups on different molecular structures which are considered as active hydrogen donors; once those hydrogen atoms are transferred, they convert radical species into stable non-radical forms. More specifically, in the DPPH assay, deep violet-colored DPPH• radical is reduced to its non-radical form (DPPH-H), leading to a visible color change from purple to pale yellow. The chromatic change reflects the radical scavenging ability of studied sample, which is proportional to decrease in absorbance at characteristic wavelength measured (indicative) by spectrophotometry[33]. Accordingly the results of present study, the potent antioxidant potential (63.28%) of the *R. alaternus* powder can be scientifically ascribed to the hydrogen-donating ability of its phenolic compounds which serve as free radical terminators and quell oxidative chain reactions.

3.2. Mineral elements

The contents of the mineral elements in *R. alaternus* fruit powder were given in ppm as shown in table (2). The findings indicate that the highest concentration was associated with calcium (Ca) - 19.35 ppm, and magnesium (Mg) - 10.50 ppm. Lead (Pb) was present in trace amounts (0.37 ppm), while iron (Fe) had the least concentration among the analyzed elements (0.20 ppm). The mineral elements showed quantitative variation in the tested sample, with the representation of calcium as the dominant element.

Table (2) Chemical estimation of mineral elements in *R.alaternus* powder

Mineral	**(ppm)**
Ca	19.35
Fe	0.20
Mg	10.50
Pb	0.37

Minerals play a vital role in the formation of body structures and regulation of various chemical reactions, although they are required in small quantities. They can vary in availability based on including environmental conditions like water supply and altitude [34]. Among these, certain minerals are vital for the maintenance of normal physiological functions and growth: calcium, phosphorus, potassium, iron, magnesium (Mg), manganese (Mn), sodium (Na), copper (Cu), and zinc (Zn) [35].

The results of the current study, shown in Table 4, indicate that the high levels of calcium and magnesium, followed by lower levels of iron, suggest underlying physiological and biochemical processes that likely control mineral uptake and distribution in plant tissues. Calcium and magnesium are macronutrients for plants, which contribute to structural integrity and metabolic regulation. Indeed, because of calcium's vital function in cell wall stability and membrane integrity, as well as its status as an internal signal orchestrating stress responses and nutrition partitioning, it accumulates with relative ease in comparison to trace elements within the tissues of fruit [36]. Previous studies conducted upon wild edible fruits reported the predominance of macroelements such as calcium and magnesium in the mineral profile due to their higher mobility and easier absorption rates from plant roots and tissues while micronutrients (iron) generally exist in lower concentrations since they are highly controlled during uptake process to avoid any oxidative stress [37] previous studies conducted upon wild edible fruits reported the predominance of macroelements such as calcium and magnesium in the mineral profile due to their higher mobility and easier absorption rates from plant roots and tissues while micronutrients (iron) generally exist in lower concentrations since they are highly controlled during uptake process to avoid any oxidative stress. The mineral analysis in this study is comparable to previous study [31] and, [38] which proves that *Rhamnus* is rich in minerals and antioxidants.

Phytochemical screening of the plant extract showed the presence of numerous bioactive compounds (Table 3). Saponins were determined by the formation of stable foam. Tannins were detected as indicated by the formation of precipitate with lead acetate. Ferric chloride test for polyphenols was positive. Yellow coloration after adding sodium hydroxide indicated flavoids. Alkaloids gave reddish-brown precipitate with Dragendorff's reagent. Reducing sugars were confirmed by the color change when heated with Benedict' s reagent.

Table 3. Phytochemical investigation Test for Plant Extract

Sapponins	Foam test	1 ml of extract + 9 ml of distilled water, agitated in a test tube for 15 seconds and left to stand for 15 minutes
Tannins	1%lead acetate test	2ml of extracts + a few drops of lead acetate (1%) solution
Polyphenols	Ferric chloride test	2 ml of extract + 2 ml 5% ferric chloride solution
Flavonoids	Alkaline reagent test	2 ml of extract + a few drops of sodium hydroxid solution
Alkaloids	Dragendroff's test	5 ml of extract + a few drops of Dragendroff's reagent(solution of potassium bismuth iodide)
Reducing sugars	Banedict's test	5 ml of extract + a few drops of Banedict's reagent +boiling on

Phytochemical studies have shown that the *Rhamnus* plant is composed primarily of a variety of essential bioactive compounds, including tannins, polyphenols, flavonoids, alkaloids, reducing agents, sugars, tannins, anthraquinones, anthocyanins, anthocyanidins, and other compounds [39]. Essential and non-essential minerals, volatile oils, and saponins are typically present in lower concentrations[40]. The main classes of secondary metabolites identified in this species include phenolics and flavonoids, which serve as important biomarkers for the plant. The findings of the current study are consistent with numerous studies indicating the presence of diverse bioactive compounds in *Rhamnus* species[11, 41-43]. A study conducted by Nekkaa *et al.,* confirmed that extracts from the fruit of the *Rhamnus alternus* plant contain a wide range of bioactive compounds with high nutritional value. The analysis revealed a high concentration of anthocyanins and various anthocyanidins, including delphinidin derivatives, cyanidin, and pelagonidin [44]. Other studies show phytochemical analysis of *Rhamnus alaternus* extracts resulted in the identification of multiple groups of naturally occurring bioactive constituents, highlighting the abundance of secondary metabolites in this medicinal species. The detected compounds comprised flavonoids, tannins, anthraquinones, anthocyanins, anthocyanidins, in addition to other related phytochemicals [39, 45].

From a biochemical perspective, phenolic compounds are the primary contributors to the antioxidant capacity of plant materials. Their activity is mainly attributed to their superior reducing capacity and their ability to donate hydrogen atoms or electrons, which are crucial for neutralizing reactive species[46]. Several studies have demonstrated the potent ability of plant polyphenols to scavenge synthetic free radicals such as DPPH and ABTS+, as well as their capacity to reduce nitrite radicals. This antioxidant property is directly related to the structural properties of phenolic hydroxyl groups, which enhance the stability of free radicals and terminate reactions [29, 46].

Yield of plant extracts

The yield of residues from *R. alaternus* fruit powder obtained the different extraction methods as presented in Table 4, significant variations in extraction yield (%) were observed among the different aqueous solvent concentrations. The highest yield of alcoholic extraction was the cold maceration with 70% ethanol method, which obtained a residue of 30.15 g/100 g of vegetable material. The Soxhlet extraction with 70 % ethanol produced a slightly lower yield (24.8 g per 100 g) while the aqueous extraction through digestion proved to be the least productive process, yielding only 10 g residue (per 100 g of plant)[47].

Table (4) Weight of Each Residue yielded from each types of extraction methods for polar components in the plant

The Fraction	**Extraction Method Type**	**% Residue** (g/100g)
Alcoholic Fraction	Cold Maceration	30.15
	Soxhlet	24.8
Aqueous Fraction	Digestion	10

Several variables influence the extraction efficiency of phytochemicals, including the chemical nature of targeted compounds, process technique, plant material particle size, solvent polarity and interfering components. Of these factors, solvent polarity plays a decisive role in the preferential solubilization of phenolic compounds, which are commonly known to be associated with antioxidant activity[48].

The results obtained in present study indicate that the solvent extraction behavior did not entirely conform to the expected pattern of progressively increasing extraction efficiency with increasing polarity. The polarity indices of commonly used solvents water (10.2), ethanol (5.2), and methanol (5.1)[49]. This deviation can be explained by biochemical components with different polar properties, considerable discrepancies in an overall extraction yield could be observed. Specifically, ethanol displays a polar profile that enables effective extraction of diverse polar compounds (e.g., phospholipids, polysaccharides, and lipoproteins) (26). In this study, extraction yields obtained for methods applied to Rhamnus fruit powder demonstrate how polarity and extraction method exert a combined effect on polar constituent recoveries. Ethanol is regarded as an efficient extraction medium, particularly when used in aqueous mixtures, because it enables the dissolution of both hydrophilic and moderately lipophilic phytochemicals, resulting in improved overall extract recovery. Wakil et al. [50] reported that solvent polarity significantly affected the total phenolic and flavonoid content of *Isatis tinctoria*, with extraction yield increasing with increasing solvent polarity up to an optimum level, then decreasing at very high polarity indices. Similarly, Kobos *et al.* [49] demonstrated that the highest yield of phytochemicals from apple pomace was achieved using a 60% aqueous ethanol solution, while a 96% ethanol solution resulted in the lowest yield. Menoubi *et al.* [51] reported similar results, noting that an 80% aqueous ethanol solution produced the highest extraction yield from prickly pear cactus (*Opuntia stricta*), attributing this to ethanol's ability to dissolve both polar and nonpolar molecules. Furthermore, Arya et al. [52] confirmed the efficiency of ethanol in extracting bioactive compounds from fenugreek seeds (*Trigonella foenum-graecum*), recording higher concentrations compared to petroleum ether, chloroform, and water, this is consistent with the results of our study.

However, the findings of the present study are not consistent with study reported by Arya *et al.*, [53] investigation on wood extracts, where water was identified as the most effective solvent in terms of extraction yield, followed by ethanol. In that study, ethanol demonstrated a higher yield compared to other organic solvents such as acetone and methanol.

Phytochemical screening for each type of plant extract

Table 5 shows the results of the preliminary phytochemical analysis of *R.alaternus* fruit extracts prepared by alcoholic cold maceration, alcoholic Soxhlet extract, and aqueous digestion extract. Phytochemicals were detected in all three extracts, with varying relative abundances. The saponin content were detected at a low level (+) in both alcoholic cold maceration and alcoholic Soxhlet extracts, whereas they were abundantly present (+++) in the aqueous digestion extract. The tannin content was moderate (++) in the cold maceration and aqueous digestion extracts and high (+++) in the Soxhlet extract. The polyphenol and flavonoid content was moderate (++) in both alcoholic extracts and abundant (+++) in the aqueous digestion extract. Alkaloids were found in all extracts (+++). The cold maceration and aqueous digestion extracts contained high (+++) amounts of reducing sugars, while the Soxhlet extract contained moderate (++) amounts. Overall, the results demonstrate variation in the intensity of phytochemical constituents among the different extraction methods, with certain compounds showing higher abundance in the aqueous extract compared to the alcoholic extracts.

Table 5. Preliminary phytochemical screening of each type of plant extract

phytochemicals	**Observation**	**Alcoholic Cold Maceration Plant Extract**	**Alcoholic soxhlet Plant Extract**	**Aqueous Digestion Plant Extract**
Sapponins	Foam Formation	+	+	+++
Tannins	White precipitate	++	+++	++
Polyphenols	Deep blue or green	++	++	+++
Flavonoids	Bright yellow color	++	++	+++
Alkaloids	orange brown precipitate	+++	+++	+++
reducing sugars	Reddish brown precipitate	+++	++	+++
*The symbols + = less present / ++= adequately present /+++: abundantly present / = —absent				

The variations in the phytochemical constituents among *R. alaternus* fruit powder extracts (aqueous digestion and alcoholic) could be attributed to the solubility of compounds into solvents which were employed during extraction procedure. The polarity of the solvent is a key factor that influences how well specific classes of bioactive compounds are extracted[11]. For instance, highly polar phytochemicals like many polyphenols and flavonoids are typically extracted through the use of more polar solvents such as water than less polar or purely alcoholic solvents[40], an investigation conducted by Alachaher *et al.*, on flaxseed (*Linum usitatissimum L*) was shared, were polar solvents yield higher phenolics and flavonoids than some non-polar counterparts, which affected the antioxidant capacity of the extracted food (80% ethanol provided highest flavonoid content and antioxidant activity)[54]. In another study, disagreement with present study , conducted by Berroukche and coworkers compared the decoction and maceration of aqueous and methanolic extracts on leaves of *R. alaternus* to study their antioxidant and hepatoprotective effects, their results indicated that extracts prepared through maceration exhibited higher bioactivity and greater effectiveness compared with those obtained by the decoction method [55]

Furthermore, extraction technique and conditions (e.g., Soxhlet heated, cold maceration performance, digestion process) affects the contact between solvent and plant tissues in terms of compound release[56]. Similar studies conducted on other plant materials have shown that the variation in extraction methods and solvent systems lead to significantly different phytochemical profile, reiterating the point that extraction parameters play a crucial role in determining abundance and type of phytochemicals obtained [57].

Sensory assessment of Yogurt

The sensory evaluation results of yogurt supplemented with *R. alaternus* fruit powder are presented in Table 6. The results indicated a statistically significant difference at the ($p < 0.05$) level, the addition of *R. alaternus* powder improved most sensory attributes compared to the control. The taste score of the supplemented yogurt was 6.40 ± 0.65, higher than the control (5.30). The treated yogurt (7.30 ± 0.56) had higher flavor enrichment than the control (6.64). For texture, the supplemented yogurt received a score of 5.60 ± 0.83 (control, 5.23). Color got 7.00 ± 0.61 and control (6.54). On the whole, acceptability of enrich yogurt with secondary ratio was 7.50 ± 0.34, higher than that of control value (7.12).

Table 6. Sensory evaluation of yogurt supplemented with *R. alaternus* fruit powder

Samples	Mean ± SE				
	Taste	Flavor	Texture	Color	Overall Acceptability
Yogurt	6.40 ± 0.65 ab	7.30 ± 0.56 a	5.60 ± 0.83 b	7.00 ± 0.61 b	7.50 ± 0.34 ab
Control	5.30	6.64	5.23	6.54	7.12
LSD value	1.665 *	1.424 *	1.561 *	1.349 *	1.365 *

The means of different letters within the same column differ significantly from one another* (P<0.05).

Sensory attributes of yogurt supplemented with *R. alaternus* fruit powder are influenced by biochemical interactions and physical alterations induced during the incorporation of plant powders into dairy matrices [58]. Fruit powders are sources of bioactive compounds (low molecular weight phenolics, flavonoids and natural sugars etc.) capable of influencing flavor perception, color intensity and textural attributes in fermented milk products [59]. The volatile aromatic constituents and mild sweetness that these compounds add can benefit taste and flavor scores, either together or separately, by increasing complexity and agreeable sensory notes themselves, as was observed when passion fruit peel powder was added to goat milk yogurt: brochure might improve at a phenolic content exceeding 1.0% (which is the most probable optimal incorporation value) from favorable functional components counterbalancing negative organoleptic properties of changed formulations [60].

Polysaccharides of dietary fibres and soluble solids in fruit powders play an important role through the protein network of yogurt, water holding capacity stabilization, as well as gel formation. This interaction can enhance viscosity and mouthfeel to provide a more acceptable texture contributing to its overall acceptance. Wang *et a*l. reported that the beneficial effects of hawthorn powder added to set-type yogurt. which demonstrated that this was because promoting homogenous protein networks in the interaction between milk proteins and other components of the fruit matrix promoting texture stability and overall physical quality [61]. The enriched color tones are blended in fortitude samples because of improved concerned chemicals and different vegetable plant petals, while findings made from the present investigation confirmed that addition or inclusion of fruit raiment changes colour parameters and can furnish attributable colours to yogurt merchandise [62, 63].

CONCLUSION

In general, *R. alaternus* fruit powder showed a good (nutritional profile with high antioxidant activity and adequate mineral contents such as; Ca and Mg). The incorporation of the fruit powder into yogurt improved sensory characteristics such as taste, flavour, colour, texture and overall acceptability significantly. These results suggest the prospect of *R. alaternus* as a natural additive for enhancing health-promoting properties in dairy food. Hence its utility in directing the development of value added foods with nutritional and health modifying functionalities.

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