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Production and quality evaluation of pomegranate peel marmalade

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Abstract

The development and assessment of pomegranate peel marmalade are the main objectives of this study. five formulations of marmalade with varying amounts of pomegranate peel, lemon juice, pectin, pectinase enzyme, and sugar. The potential of the developed product as a good-quality commercial food item in the market. Moreover, it has shown promising results for the preparation of ready-to-use food products. In order to make use of the unique properties of this product, manufacturers will have the opportunity to create a range of convenient and healthy foods that will cater specifically to the needs of individuals with busy schedules. The findings demonstrated that the designed marmalade had higher nutrients. The marmalade is rich source of fiber, protein, carbohydrate, vitamins according to the nutritional analysis, making it a nutritious diet choice for all age groups. Overall, the research points to the possibility that the pomegranate peel marmalade is a good choice for people who need a yummy breakfast. This pomegranate peel marmalade developed has demonstrated an acceptable sensory and nutritional profile; they can safely store them in glass bottles if they are in good condition. Considering that developed marmalade has several positive attributes, it holds significant potential for commercialization due to its novelty and positive aspects.

Keywords: Pomegranate peel marmalade, *Punica granatum* L., lemon juice

Introduction

The pomegranate tree (*Punica granatum* L.), a member of the Punicaceae family, yields a traditionally eaten fruit with therapeutic properties. The pomegranate is an aspherical fruit with a thick, reddish-brown or yellow skin and many seeds (Alsubhi *et al.*, 2022) [3]. The fleshy covering of the seeds is given a name, and each seed is encircled by a transparent sac holding the scarlet fluid. The seeds are separated from one another by a pericarp that incorporates multiple arils. Pomegranate cultivation originated in the Middle East and spread to some arid and semi-arid regions of the world, including Brazil, particularly in the northeast. There are many countries that grow and produce pomegranates outside of Iran, Afghanistan, India, and the Mediterranean region, including Morocco, Spain, Turkey, Tunisia, Egypt, and the Middle East (Wanderley *et al.*, 2023; Zulfia Ikromovna, 2023) [25-26].

FAO (Food and Agriculture Organization) data on production and cultivated areas is lacking despite the fact that pomegranates are grown all over the world in a variety of climatic conditions. Estimates indicate 5-7 million metric tons of production, and the majority concentrated in the Middle East and India (Jain *et al.*, 2023) [13]. In Italy, pomegranate is not among the leading fruit crops, but its cultivation increased significantly in the last few years. Recent data (2021) of harvested fruits report a production area of 1249 ha with a total harvested production of 18,697 t of fruits (Ferrara *et al.*, 2023) [9]. Iran, India, the Mediterranean nations of Spain, Turkey, Tunisia, and Egypt, as well as Middle Eastern nations, are the primary pomegranate-producing and growing areas.

Processing waste has always been a major issue that pollutes the environment, and now thanks to the work of scientists, this waste is no longer a byproduct but rather a source of several potent chemical compounds with uses in the food, pharmaceutical, and industrial sectors. Worldwide, there is a lot of interest in science and the treatment of viral diseases (Hikal *et al.*, 2022) [11]. When appropriate processes and technologies are applied, pomegranate waste becomes a useful substrate to be transformed into different components. The synergistic interactions of the pomegranate with various bioplastic materials, notably in food packaging, have been the subject of numerous research studies in the last year. The major waste coming out in pomegranate food product industries and less amount in non-food industries (Ge *et al.*, 2021; Pareek *et al.*, 2020) [10, 22].

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Research has recently focused on the development of sustainable technologies to address the future demands of a growing population and to protect the environment. Processing waste has always been a major issue that contributes to environmental pollution. However, thanks to the efforts of scientists, waste is no longer a product to be ignored but rather a source of many useful chemical compounds with applications in the food, pharmaceutical, and industrial sectors (Hikal *et al.*, 2022; Zulfia Ikromovna, 2023) [11, 26]. Pomegranate peel and seeds, which are byproducts from the juice and concentrate industries that use pomegranates, provide a variety of medicinal and nutritional benefits. Therefore, using seeds in the food industry would be more beneficial than using them as animal feed or in industrial cosmetics (Kalamara *et al.*, 2019) [14].

Globally, a variety of fruit jams, jellies, marmalade, and beverages are available, and consumption of these products is increasing due to consumer awareness of their health and nutritional benefits (Bhanj *et al.*, 2021) [4]. Nowadays, marmalades are a type of preserve created from the juice and peel of citrus fruits that have been simmered with sugar and water. The term Marmalade is now used to denote a citrus jam with candied peel particles. Marmalade is commonly linked with oranges; however, other citrus fruits are suitable for marmalade (Mahmood Qureshi & Mahvish Zahra, n.d.). Orange marmalade is commonly enjoyed as a nutritious breakfast spread over a slice of bread. Kissan, Tops, Fruitoman, and many more brands of marmalade are available on the market, including sugar-free marmalade, diabetic orange marmalade, no-carb orange marmalade, and so on. Now, pomegranate peel marmalade has a highly distinctive, harsh, sweetly bitter taste and promotes health by providing nutritious components (Inam *et al.*, 2013) [12].

Marmalade is made from citrus fruits such as lemons, limes, grapefruits, mandarins, sweet oranges, bitter oranges, and other citrus fruits, or any combination of them. But I made an inventive marmalade with pomegranate peels as the main component. The hedonic scale rating determines the physical quality of marmalade (Kasav Research Student *et al.*, 2019) [15]. It is a sort of sensory assessment. Marmalades are gel-like spreads created by boiling juice or shredded peel with sugar. Marmalade retains the natural colour and flavor of the fruit from which it is prepared. Furthermore, other chemicals, such as citric acid or gelling agents, most often pectin, can be used. In traditional marmalade production, all of the components are blended in appropriate proportions, and the mixture is concentrated by performing heat treatments at normal or decreased pressure to get the intended final soluble content (Fadly *et al.*, 2021; Mohammadi-Moghaddam & Firoozzare,

2021) [8, 19].

Materials and Methods

Collection of raw materials

In India, pomegranate are majorly cultivated Maharashtra, Karnataka, Andhra Pradesh, Gujrat and picking fast in Himachal Pradesh. Bhagwa is a popular variety for edible usage in India as it has dark red colour (Sharma & Babu, 2022) [24]. The fully healthy and fresh pomegranates were collected from local market in Phagwara, Punjab, India. Peels were used in the experiment and granular sugar, pectin, lemon juice, water, equipment and other materials were used from the cooking laboratory stock.

Processing of pomegranate peel

Processing of pomegranate peel was done by the following ways. Inner whitish portion (flavedo) of the pomegranate peel was removed by a sharp knife. Then clean the peels under running tap water. Cut the peels and ribbon-like strips for more spreadable results. The slices of pomegranate peel were pretreated using a water bath at 35 degrees Celsius for 6 hours.

Pre-treatments

The pretreatment of pomegranate peel marmalade is done by two methods. Thermal treatment and enzymatic treatment. The enzymatic pretreatment is done using water bathing. Take the thinly sliced pomegranate peel, which weighs 10 grammes in each of the five beakers (250 ml), and add 100 ml of distilled water. And add pectinase enzyme powder in 0 g, 0.2 g, 0.4 g, 0.6 g, 0.8 g proportions. And mixed well, fully covered with water and aluminum foil paper, and placed in a water bath at 35 degrees Celsius for 6 hours for enzyme inactivation, softening of the peel, and reducing bitterness. After each treatment, I will check the total phenolic content, total flavonoid content and DPPH.

Preparation of pomegranate peel marmalade

The marmalade preparation is done by the following ways. All the required ingredients were weighed correctly. Granulated sugar and pectin were mixed thoroughly. The pretreated pomegranate peel and water added into a saucepan and cooked for 5 minutes. The mixture was boiled up to 65 degrees brix (TSS). Sugar pectin mix and lemon juice was added. The mixture was boiled up to 67 degrees brix (TSS). The prepared marmalade was poured into sterile glass bottles immediately. The prepared marmalade was cooled properly, after then paraffining was done. The bottles were capped properly. The marmalade stored at room temperature.

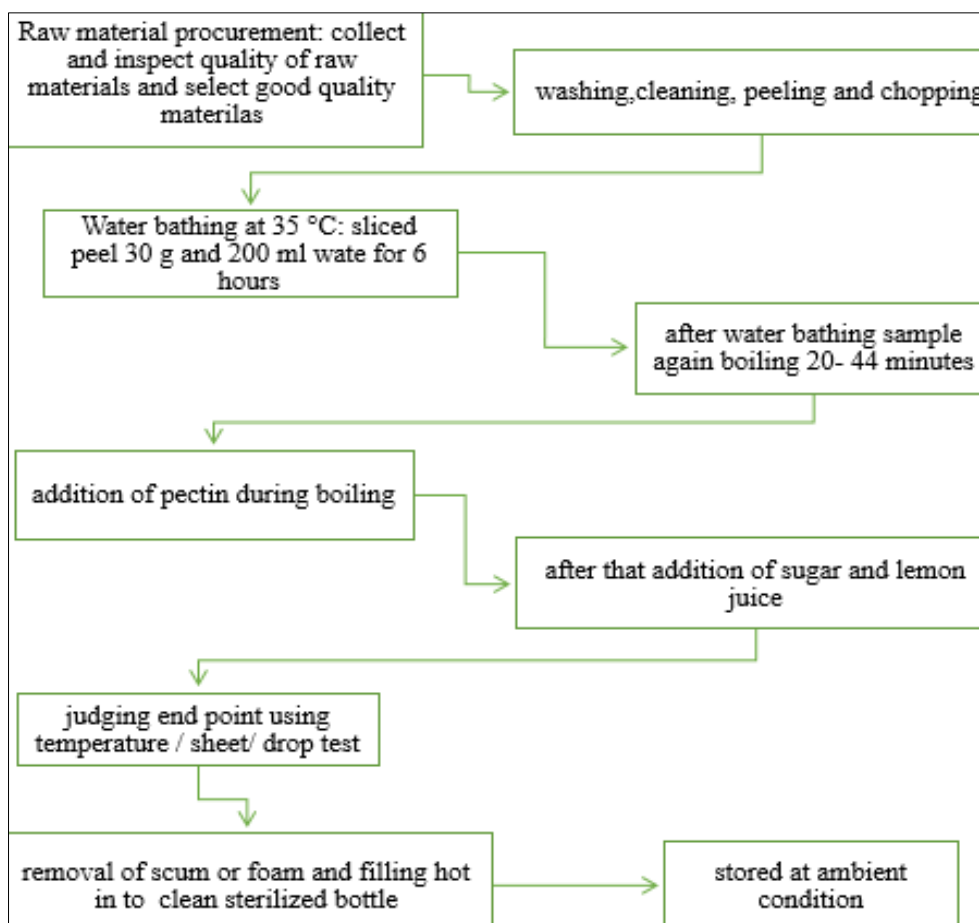


Fig 1: processing flow chart of pomegranate peel marmalade

Different samples of pomegranate peel marmalade were prepared according to the pectinase enzyme treatments given below;

Table 1: Formulation of pomegranate peel marmalade

Sample	Pomegranate peel	Water	Pectinase enzyme	Pectin	Sugar	Lemon juice
PM-1	30 g	150 ml	0%	0.5%	30 g	1%
PM-2	30 g	150 ml	0.2%	0.5%	30 g	1%
PM-3	30 g	150 ml	0.4%	0.5%	30 g	1%
PM-4	30 g	150 ml	0.6%	0.5%	30 g	1%
PM-5	30 g	150 ml	0.8%	0.5%	30 g	1%

OM= Control, PM-1 = no pectinase enzyme, PM-2 = 0.2% pectinase enzyme, PM-3 = 0.4% pectinase enzyme, PM-4 = 0.6% pectinase enzyme, PM-5 = 0.8% pectinase enzyme

Proximate analysis of pomegranate peel marmalade

Total soluble solid (TSS)

In order to estimate the total soluble solids, a hand refractometer (model ERB-32) was used. It was calibrated using distilled water and a drop of freshly squeezed juice was placed on the plate and the TSS value was expressed as OBrix.

Determination of pH

The pH content of pomegranate peel marmalade was evaluated using a pH meter method. pH calibrated with buffer solutions of pH 4.0 and 7.0, the pH was measured in accordance with the procedure detailed in AOAC (2010). In order to determine the product's level of alkalinity or acidity, the pH was tested by immediately putting electrodes into a 10 ml beaker holding the sample. Before moving on to the next

sample, the pH meter was cleaned with distilled water immediately after use (Kasav Research Student *et al.*, 2019) [15].

Moisture content (MC)

The Moisture determination was performed by drying oven method. Moisture was calculated by the difference in the mass of the sample before and after drying. 10 g of the Sample was taken in Petri dish and dried in hot air oven at 105 °C for 4 h (Castro Sousa *et al.*, n.d.).

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W} \times 100$$

Where;

W₁= weight of sample before drying with petri dish, W₂= weight of sample after drying, W= is the initial weight of the sample taken for drying.

Ash content (TA)

The ash content of pomegranate peel Marmalade was determined by Muffle Furnace. Note the weight of empty silica crucible. Weigh 10 ml of the sample into the crucible. Flash off the moisture using a water bath. Keep the content at 550 °C for 6 hours in a muffle furnace. Cool the dishes in desiccators & weighed them. Note the difference in the weight of content. Calculate the ash content in% (Kasav Research Student *et al.*, 2019) [15].

$$\text{Total ash content (\%)} = \frac{W_n - W_1}{W_s} \times 100$$

Where;

W_n = final weight of the sample, W_i = initial weight of the empty crucible, W_s = weight of the sample.

Protein content (PC)

The protein content of pomegranate peel marmalade was determined by Kjeldhal method. The sample is completely oxidized with concentrated H_2SO_4 to produce ammonium sulphate, which is an inorganic form of nitrogen derived from the protein and other nitrogenous substances. Ammonia is released from ammonium sulphate by treating the digest with more than 50% NaOH. After being gathered in boric acid, the ammonia is titrated with regular H_2SO_4 (Elfalleh *et al.*, 2022) [7].

$$\text{Nitrogen\%} = \frac{(\text{BR} - \text{Blank}) \times N \times 14}{W_s \times 1000}$$

Where;

BR is burette reading, N is normality HCl used for titration and W is weight of sample.

$$\text{Crude protein\%} = \text{Nitrogen content} \times 6.25$$

Where; 6.25 is the multiplication factor.

Crude fat content (CF)

The fat content of pomegranate peel marmalade determined using Soxhlet extraction method. The marmalade-dried sample was weighed and rolled in filter paper. The filter paper is kept in thimble and placed in pre-weighed glass vessel. Further, 90 ml of hexane was added and the extraction was done with standard program in automatic Soxhlet equipment (Castro Sousa *et al.*, n.d.).

$$\text{Fat content (\%)} = \frac{W_n - W_1}{W_s} \times 100$$

Where;

W_n = final weight of the sample, W_i = initial weight of glass vessel, W_s = weight of the sample.

Crude fiber content (CFc)

The fiber content of pomegranate peel marmalade was determined using the acid-alkali technique. The sample was first added and cooked with 1.25% H_2SO_4 and 1.25% NaOH before being free of moisture and fat. The digested sample was then dried after filtering through Whatman filter paper that had been pre-weighed. Further, the dried sample was weighed and subjected for estimation of ash content (Mahmood Qureshi & Mahvish Zahra, n.d.).

$$\text{Fiber content (\%)} = \frac{W_1 - (W_o + W_a)}{W_s} \times 100$$

Where; W_i = final weight, W_o = initial weight of empty filter paper, W_a = weight of ash content, W_s = weight of sample

Total carbohydrate content (TC)

The total carbohydrate content was determined by the difference method. The macronutrients and moisture in the product were taken to be considered to be equal to 100%, and the number of carbohydrates was determined by deducting

other elements from 100%. The calculation done by the following equation (Castro Sousa *et al.*, n.d.).

$$\text{Total carbohydrate (\%)} = 100 - \text{Moisture} + \text{Ash} + \text{Protein} + \text{Fat} + \text{Dietary fiber}$$

Total sugar (TS)

Total sugars were assessed using anthrone method given by Scott and Melvin (1953) [27]. Anthrone reagent was prepared by dissolving 0.05% of anthrone in concentrated sulphuric acid. For preparing the sample, 2 grams of fruit pulp was taken and macerated using 100 ml of distilled water. Then, 1 ml of fruit sample was transferred into a test tube and 1 ml of distilled water and 3 ml of anthrone reagent was added to that. Thereafter, the test tube was kept in a water bath at 100 °C for 15 minutes. Absorbance was recorded at 625 nm against blank and then for sample. Total sugars were calculated using following formula and expressed in percentage (Inam *et al.*, 2013) [12]

$$\text{Total sugar (\%)} = \frac{\text{O. D of sample}}{\text{O. D of glucose}} \div 10$$

Ascorbic acid content (AC)

Two grams of marmalade sample was macerated using mortar and pestle by adding 100 mL of 3% metaphosphoric acid. Thereafter sample was filtered with muslin cloth and 10 mL aliquot was taken from the sample in a conical flask and titrated with 2, 6-dichlorophenol-indophenol dye till pink color appeared and abide for 15 seconds. The values were noted and expressed in mg per 100 g of pulp. (A.O.A.C. 2010) (Du *et al.*, 2019) [6].

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up} \times 100}{\text{volume of aliquot} \times \text{Weight of sample taken}}$$

Sensory analysis of pomegranate peel marmalade

It was determined whether developed products were acceptable to consumers by a testing panel. This acceptance was assessed using the hedonic rating test. The tasting panel was consisting of 30 members. The products were evaluated based on the score. The panelists were chosen from a range of socioeconomic status. On a scale from "dislike extremely" to "like extremely," the panelists were asked to score their acceptance for the product on a hedonic scale, from 1 to 9. Each scale point is given a numerical value in order to statistically analyses the outcome (Inam *et al.*, 2013) [12]

Statistical analysis

Using IBM SPSS software (a multivariate post-hoc test, followed by Duncan's test), the data's normality was investigated in order to find the interactions between significant values. As a consequence, an ANOVA was performed to determine how the treatments differed from one another, and the least significant difference test ($p < 0.05$) was applied for several meaningful comparisons between the treatment mean values. Additionally, the program was used to calculate the mean, standard deviation, and standard errors. Using Microsoft Excel, a graphical presentation was created.

Result and Discussion

Total soluble solid (TSS)

The total soluble solid (°Brix), of different marmalade samples has been represented in Table 2. There was a

significant difference in TSS among the all samples. The component, which affects the taste of products, is the sugar content. The highest value was obtained from sample PM-1 (67.64 °Brix) and the lowest value was obtained from sample PM-5 (65.3 °Brix). In pomegranate peel marmalade, the amount of pectinase enzyme powder increased in proportion to a decrease in total soluble solids (°Brix). The TSS range varied from 65.3 °Brix to 67.64 °Brix. Sample PM-2 and PM-3 has been the same TSS (67.1 °Brix), and PM-4 is ranged from (67.43 °Brix). TSS content of 65.5 °Brix to 68.95 °Brix has been reported in mixed fruit marmalade, whereas, in cherry marmalade TSS content of 67.3 °Brix to 68.5 °Brix has been found (Inam *et al.*, 2013) ^[12]

pH

The results (table 2) showed a significant ($p < 0.05$) effect of pectinase enzyme powder treatments on the pH of the pomegranate peel marmalade. The pH of the sample gradually decreased with an increase in pectinase enzyme powder concentration in pomegranate peel marmalade. The highest pH value of pomegranate peel marmalade was obtained from PM-1 (3.13%) and the lowest value was obtained from sample PM-5 (2.7%). Sample PM-2 and PM-3 has the same value (2.8%) and the sample PM-4 was obtained with significant difference (2.83%). A similar study conducted in sapota marmalade incorporated with orange peel ranged from 2.7% to 3.3%, whereas, in orange marmalade pH content is 3.5% to 3.8% has been found (Inam *et al.*, 2013) ^[12]

Moisture content (MC)

The Sample S5 (24.7%) had the greatest moisture content of pomegranate peel marmalade, while sample S1 (21.9) had the lowest moisture content. Moisture content varied significantly among samples S2, S3, and S4 (table 2). On the other hand, moisture content increased with increase the concentration of pectinase enzyme powder in pomegranate peel marmalade. As a result of the heating process that is involved in the processing, the fluctuations in moisture content observed might be explained by this. During the process of making marmalade, water was removed during the cooking process, leading to a change in the concentration of nutrients in the food. Each formulation in the research differed significantly from the others, indicating that it had a statistical advantage over the others. Statistics show that the observed variances in the formulations are substantial. showing that each composition has certain qualities. The moisture content contributes to marmalade's spread ability and juiciness (Kasav Research Student *et al.*, 2019) ^[15].

Total ash content (TA)

Ash content of prepared marmalade samples found in the range of 0.936% to 2.38%. The sample PM-3 had the highest ash content (2.38%) followed by the sample PM-5 and PM-2 (1.84%) (1.48%), while sample PM-4 and PM-1 had the lowest ash content (0.936%) (0.94%). Ash content of different samples comparable to other studies reported by (Inam *et al.*, 2013; Mahmood Qureshi & Mahvish Zahra, n.d.) ^[12]. Marmalade generally contains less ash. Marmalade doesn't include much mineral content because it's mainly consisted of fruits and sugar. The type of fruit used and any other ingredients added to the recipe, among other things, might have a modest impact on the ash content. The ash content 0.18% and 0.29% has been reported in sapota marmalade

(Oruonye *et al.*, 2021) ^[21] whereas, in orange with addition of aloe vera powder marmalade an ash content 0.27 to 0.93 percent has been found (Mahmood Qureshi & Mahvish Zahra, n.d.). Similar study conducted by mixed fruit marmalade, the ash content in different samples ranged from 1.02% to 2.13% (Kasav Research Student *et al.*, 2019) ^[15].

Protein content (PC)

A healthy diet must contain protein since it provides nitrogen (N) and amino acids to the body. Amino acids are used to make a variety of non-protein nitrogenous compounds, including glutathione, creatine, neurotransmitters, neuropeptide hormones, and nucleic acids, all of which are crucial for metabolism. The carbon skeleton of amino acids can also be used as an energy source or in different metabolic processes through a process known as deamination. Overall, dietary proteins and amino acids are essential for maintaining bodily function and play a role in a variety of physiological processes and biochemical reactions (Pastuszka *et al.*, 2021) ^[23].

The protein content in the different samples of pomegranate peel marmalade varied with in a range of 1.76% to 3.4%. Among the five different sample, it was observed that PM-5 exhibited the highest protein content measuring at 3.4%. In comparison, PM-4 (2.28%), PM-3 (2.23%), PM-2 (2.26%) and PM-1 (1.76%) has the lowest protein content among the marmalade samples. The protein content of PM-1 was found to be significantly higher than that of the other samples, indicating notable differences in protein compositions between the rest of the samples.

Crude fat content (CF)

The fat level of the various marmalade samples ranged from 2.13 to 3.74 percent. Among these samples, PM-4 showed the highest fat content, measuring 3.74 percent, in comparison of the other samples. This indicates that PM-4 has a relatively higher fat content compared to the rest of the samples. Sample PM-1 (2.13%) and sample PM-5 (2.4%) is the lowest fat content were obtained, the rest of the samples PM-3 (3.5%) and PM-4 (3%) varied significant difference in fat content. Several studies have reported on the use of fruit peel in preparation of marmalade and jams, however all authors reported very low amount of fat, 0.72% to 1.85% in mixed fruit marmalade (Inam *et al.*, 2013) ^[12] and 0.92% to 2.05% in to sapota marmalade (Fadly *et al.*, 2021) ^[8]. The range of fat content found to be different samples tabulating in table 2.

Crude fiber content (Cfc)

Several methods are used to assess the quality of plant-based foods, including determining their crude fiber content. In case of marmalade, the crude fiber content varied between 2.95% to 3.89% across different samples. The fiber content of the sample gradually decreased with increase in pectinase enzyme powder concentration in pomegranate peel marmalade. Among the samples, PM-1 (3.89%) is displayed the highest fiber content compared to other samples. The observed results in fiber content indicates differences in the dietary fiber compositions among the samples, with PM-1 is demonstrating the highest content of indigestible fraction. The lowest fiber content from the sample PM-5 (2.95%) and the other values are samples PM-2 (3.35%), PM-3 (3.2%) and sample PM-4 is obtained 3.15% of fiber content. A high-fiber diet has a number of advantages on physical health. Along with having

positive effects on the gastrointestinal system, it has the ability to aid in weight reduction and lessen irregularities in glucose and fat metabolism. According to recent studies, whole grain cereal products containing insoluble dietary fibers are particularly effective at reducing type 2 diabetes mellitus (Abd El Moneem *et al.*, 2021; Mansour *et al.*, 2020) [1, 18].

Total carbohydrate content (TC)

Carbohydrates serve as the primary source of energy, providing approximately 4 Kcal per gram. Additionally, they play a significant role as thickening agents in marmalade, particularly through the use of starch. In terms of carbohydrate content, statistically significant difference was observed among the formulations. The carbohydrate content ranged from 64.8% to 69.7%, with PM-1 (69.7%), PM-2

(66.76%), PM-3 (66.51%), PM-2 (66.39%) exhibiting higher amounts of carbohydrates compared to PM-5 (64.81%) respectively. In similar study conducted by (Inam *et al.*, 2013; Kasav Research Student *et al.*, 2019) [12, 15] the total carbohydrate content in the marmalade varied between 54.4% and 62.95%. These values were significantly lower ($p < 0.05$) than all the treatments evaluated. The pomegranate peel typically contains carbohydrate in the range of 65% to 76.61% (Omar & Mehder, 2019) [20]. Additionally, the carbohydrate content is present in other ingredients (Mahmood Qureshi & Mahvish Zahra, n.d.). Carbohydrates are the body's primary source of energy, and they are the primary component of food. A high carbohydrate content in marmalade can provide a quick and easy source of energy that is easily digestible (Ko *et al.*, 2021) [16].

Table 2: Proximate analysis of pomegranate peel marmalade

	PM-1	PM-2	PM-3	PM-4	PM-5
	Mean \pm SD	Mean \pm SD	Mean \pm SD	Mean \pm SD	Mean \pm SD
Moisture (%)	21.56 \pm 0.1 ^a	22.43 \pm 0.58 ^b	22.6 \pm 0.58 ^b	23.5 \pm 0.1 ^c	24.5 \pm 0.01 ^d
Ash (%)	0.94 \pm 0.9 ^a	1.48 \pm 0.01 ^b	2.38 \pm 0.01 ^d	0.936 \pm 0.09 ^a	1.84 \pm 0.01 ^b
TSS (%)	67.64 \pm 0.17 ^b	67.1 \pm 0.17 ^b	67.1 \pm 0.17 ^b	67.43 \pm 0.17 ^b	65.3 \pm 0.1 ^a
pH (%)	3.13 \pm 0.01 ^b	2.8 \pm 0.22 ^a	2.8 \pm 0.22 ^a	2.83 \pm 0.22 ^a	2.7 \pm 0.22 ^a
Carbohydrate (%)	69.7 \pm 0.1 ^c	66.7 \pm 0.313 ^b	66.5 \pm 0.313 ^b	66.3 \pm 0.313 ^b	64.8 \pm 0.01 ^a
Fat (%)	2.13 \pm 0.1 ^a	3.5 \pm 0.124 ^d	3 \pm 0.01 ^c	3.74 \pm 0.124 ^d	2.4 \pm 1 ^b
Protein (%)	1.76 \pm 0.1 ^a	2.67 \pm 0.063 ^b	2.23 \pm 0.063 ^b	2.28 \pm 0.063 ^b	3.4 \pm 0.01 ^d
Dietary fibre (%)	3.89 \pm 0.1 ^c	3.35 \pm 0.1 ^d	3.2 \pm 0.01 ^c	3.15 \pm 0.1 ^b	2.95 \pm 0.1 ^a

Note: Values are means \pm standard deviation of three determinations. Values with different super-script on the same row are significant ($p \leq 0.05$).

Total sugar (TS)

The selected ingredients of the marmalade belong to high sugar content, and the total range of sugar varied from 63.7% to 66.1%. The sugar content is highest in PM-1 (66.1%) followed by PM-2 (65.56%), PM-3 (65.14%), PM-4 (64%) and least sugar content found in PM-5 (63.7%) respectively. Sugar is essential to how marmalade tastes and appears. A pleasing flavour profile is produced by balancing the sugar's sweetness with the citrus fruit's acidity in marmalade. Sugar contributes to the distinctive texture and consistency of marmalade by aiding in the preservation and gelling processes. Because marmalade contains a lot of sugar, it reduces water activity and prevents the growth of bacteria, acting as a preservative. This keeps the product's quality consistent over time and increases its shelf life. The jelling process in marmalade requires both reducing and non-reducing sugars to function. Pectin, a naturally occurring gelling ingredient present in fruits, works in conjunction with citrus fruit acidity to produce the desirable gel-like texture. To achieve the right gel structure and maintain the marmalade, the sugar concentration, including both reducing and non-reducing sugars, is important (Fadly *et al.*, 2021) [28].

Ascorbic acid content (AC)

Ascorbic acid (Vitamin C) content in pomegranate peel treated with pectinase enzyme marmalade sample PM-3 (12.95%) were found very low amount compared to pomegranate peel marmalade sample PM-1 (23%). Because most of the ascorbic acid present in peel and arils, they were destroyed during long heating with enzyme treatments. Together with this ascorbic acid is highly volatile micronutrient. The composition that was found may vary due the variety, environment and maturity affect (Abbas Syed,

2018) [1]. Sample PM-4 I (20.55%) is found in good vitamin c content and PM-2 (12.9%) is also good source of vitamin C respectively. The quantity of vitamin C in pomegranate peel hasn't been extensively studied, but studies that have been done on the topic have found that the peel can contain a lot of the vitamin. Compared to the fruit's edible arils (seeds) and juice, pomegranate peel typically has a lesser concentration of vitamin C, but it nevertheless adds to the fruit's total nutritional worth. A similar study conducted in sapota marmalade incorporated with orange peel ranged from 13% to 18.3%, whereas, in orange marmalade vitamin C content is 18.5% to 29.8% has been found.

Sensory analysis of pomegranate peel marmalade

Sensory evaluation is fundamental to the development of food products since it keeps the risk of product failure at a minimum as well as shows a customer's perception of how a food will taste and how it will be perceived by them. A skilled panel of judges evaluated the product based on its sensory attributes, including color and appearance, consistency, flavor and sweetness, mouthfeel and overall acceptability as a whole. Using a 9-point scale, a group of skilled judges evaluated the sensory aspects of appearance, consistency, flavor, taste, and overall acceptability.

The highest value followed by PM-1 while PM-2 and PM-3 got the lowest value for the sensory attributes. The score of control for color and appearance, consistency, flavor and sweetness, mouthfeel and overall acceptability are 7.62, 7.37, 7.43, 7.37 and 7.51 respectively. Due to the addition pectinase enzyme treatment that gave the sample very palatable sensory, the sample PM-1 had the greatest value of flavor. Natural flavor or off-notes may be present, which consumers may find unwanted or unpalatable. The addition of an enzyme

can be used to hide or lower the value of certain nutrients, enhancing consumer acceptance and satisfaction with the final product. Food producers have the opportunity to reduce any undesirable flavor and mouthfeel qualities and produce more favorable sensory experiences for customers by introducing pectinase enzyme powder. Among the improved sample the variation PM-1 scored the highest score than other variations for all the sensory characters wise color and appearance (8.17), consistency (8.2), flavor and sweetness (8.56), mouthfeel (8.64) and overall acceptability (8.33). PM-1 consisting of like very much color and appearance, liking very much consistency shows high acceptance among the judges which were similar to commercial product and flavor also moderate without any kind of bitterness. For all the pomegranate peel marmalade sample sensory responses like color and appearance, consistency, flavor and sweetness, mouthfeel and overall acceptability were different to and it was evident from the data that there exists significant difference at $p \leq 0.05$ in between the marmalade sample with respect to appearance.

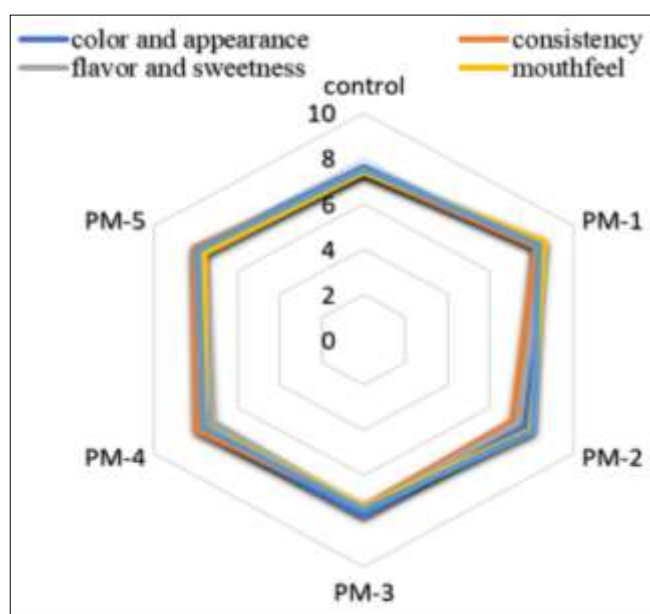


Fig 2: Sensory evaluation of different sample of pomegranate peel marmalade.

Conclusion

Pomegranate peel has potential health advantages, although most of research have used isolated chemicals extracted from the peel rather than the whole peel. Additionally, eating pomegranate peel straight up could be just as tasty as eating fruit peel that has been used to produce culinary products. The findings of the current investigation showed that the physio-chemical and sensory characteristics of pomegranate peel marmalade were considerably impacted by the addition of various concentrations of pectinase enzyme powder. It was discovered that when pectinase enzyme powder concentration in pomegranate peel grew, pH, brix, and fat contents of marmalade reduced while moisture, protein, and fiber contents also increased. PM-1 (Without pectinase enzyme powder) had the best sensory qualities in terms of color, taste, texture, flavor, and overall acceptability of pomegranate peel marmalade, but PM-5 (0.8 g pectinase enzyme powder) received the lowest marks from the judges. Therefore, it is advised to make the marmalade without adding any enzyme.

The Marmalade PM-1 prepared from 30 g of fresh pomegranate peel thinly shredded, and 150 ml of water along with water bathing 35 C for 6 hours. Then add poured in to the saucepan and add other ingredients were found acceptable in terms of all sensory parameters was found best among all combinations. The acceptable proximate was also found in PM-1 followed by PM-3. The result indicates that enzyme addition with pomegranate peel significantly enhanced the nutritional characteristics like high fiber and low fat. Considering that developed marmalade has several positive attributes, it holds significant potential for commercialization, due to its novelty and positive aspects.

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