

Replacing Pectin with Date Seed Powder as a Sustainable Natural Ingredient in Mango Jam to Improve its Qualitative Characteristics During Storage

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Abstract

The valuation of agro-industrial by-products is progressively considered a sustainable food production strategy. This work assessed the physiochemical, rheological, sensory and microbiological properties of mango jam supplemented with 0% (T0), 25% (T1), 50% (T2), 75% (T3) and 100% (T4) of commercial pectin with date seed powder from dates in Morogoro using standardized methods during a period of 60 days under refrigeration at a temperature of ~4 °C. The total solids (50.40–54.45%), ash (0.26–0.83 g/100 g), crude fibre (0.42–1.51 g/100 g), viscosity (1088–1508 cP) and antioxidant activity (17.21–22.67%) were considered significant variables with positive trends through DSP; this is contrasted by increased deposits in the total solubility due to losses in DSP. DSP-treated samples had a significantly lower amount of bacteria and fungi during storage. Sensory evaluation determined T3 to be optimal with the greatest overall acceptability (8.10/9) Conclusions: DSP is an attractive and practical, greener natural substitute of pectin-type made commercially in mango jam.

Keywords: Date seed powder; Mango jam; Pectin substitution; Antioxidant activity; Functional foods; Agro-industrial valorization; Storage stability.

1. Introduction

So, supply and demand for sustainable products from the consumer side, by environmental pressure, and valorisation of agro-industrial by-products (which otherwise would be disposed of) are transforming the food industry into Sustainable Production in a very short time. Humans have recently adopted the use of plant-based residues owing to their environmental advantages as well as good nutritional potential [1] for developing functional food ingredients as a plausible strategy in this domain.

Date palm (*Phoenix dactylifera* L.), one of the most economically important, accounts for almost 70% of total world production in 2022 and over 97.5 million tons were produced in the Middle east and North Africa region [1]. Processing produces a massive number of date stones (also called

as pits or seeds), which account for ~10–15% of the total weight of the fruit, translating into an annual figure of 750,000tons on an international level. Nonetheless, while their bioactive composition is rich, and their economic potential is high, most are only employed for low-value applications such as animal feed [2].

The equally biocompatible composition of date seeds is important when using their components as functional ingredients. They are a natural source of dietary fibre (57.24–80.2 g/100 g), proteins, lipids, and a variety of phenolic compounds, including gallic, caffeic, ferolic, and p-coumaric acids and catechin and epicatechin [3, 4]. The plants had 448 mg of GAE/100 g of total phenolic compounds and an antioxidant activity of 87% of GAE/100 g

and justifying the functional properties such as antioxidant, antimicrobial and anti-inflammatory [5].

Pectin is a gelling agent that hydrolyzes with sugar and acid to form strong gel and is mainly used for producing jam. To date, in developing countries, it is primarily extracted from citrus peel and apple pomace through resource-intensive methods involving imported raw materials [6] (Roman-Benn et al., 2023). These disadvantages of CMC, along with the narrow functional features of CMC, have encouraged research on other natural hydrocolloids that could provide technological purposes [7] in combination with better nutritional value. Various by-products of plants such as peels of mangos, wastes from citrus fruit, and powders from tubers have been studied but with varying effectiveness [8].

Various recent research works have validated the role of date seed powder (DSP) as a pectin replacer. The addition of DSP to strawberry jam resulted in its formulation enriched with dietary fibre, ash and antioxidant activity, while reducing water activity, without negatively affecting overall sensory quality [9]. This enhancement was also apparent for date-based products augmented with plant residues [10]. Bikila et al. Plant-based powders can be used as a substitute for pectin while maintaining physicochemical stability of jam systems and confirmed that proposition in their recent work Pectine in jam systems [10].

Mango (*Mangifera indica* L.), a king fruit, is extremely rich in sugars, carotenoids, phenolics, vitamin C, and natural pectin (from the pericarp), is an example of a jam pattern preparation [11, 12]. However, pectin when specifically added remains an artificial component in industrial mango jam, raising the same question whether DSP from mango peels can be an

alternative functional, value-added, yet economic, and healthier ingredient.

While DSP has been studied in bakery and dairy applications, mango jam has received limited use. Thus, the aim of this study was to investigate the influence of partial replacement of pectin by DSP at (25, 50, 75 and 100%) on the physicochemical, antioxidant activity, sensory and microbiological characteristics of mango jam during 60 days of storage and to determine the optimum level of substitution which will enhance the nutritional quality with acceptable sensory properties.

2. Material and Methods

2.1 Raw Materials

Fully ripened mango fruits, with a homogeneous golden-yellow colour and no visible defects collected in local markets. Medium-grade date fruits were obtained from the same source, then their seeds were isolated, cleaned, dried and ground into powder. Commercial high-methoxyl pectin (HMP), sucrose, citric acid and sodium benzoate were obtained from local authorized suppliers who provided food grade products.

2.2 Preparation of Date Seed Powder

Preparation of Date seed powder: Date seed powder was prepared by following the modified protocol of [9] (Alqahtani, 2020) All seeds were washed using running water to remove residual pulp, soaked in lukewarm water (at 60 °C) for 12 h (as this time is often used as a standard protocol to promote managing the softening process), then washed again and dried in an electric oven at 60 °C for 24 h until reaching a constant sample weight. The dried seeds were then roasted at 120 °C for 30 minutes in order to improve

grindability and develop a lightly aromatic profile. The roasted seeds were milled with an electric grinder at high speed and passed through a 0.5 mm mesh to yield fine, homogeneous powder. The final product DSP was stored in vacuum-tight containers at room temperature, shielded from light and moisture until needed.

2.3 Preparation of Mango Jam

Samples of mango jam were made with sequentially higher addition levels of date seed powder as a substitute for pectin. The samples for which pectin was replaced by DSP were denoted as T0 (zero), T1 (25 %), T2 (50 %), T3 (75 %) and T4 (100 %). Other ingredients such as sugar, citric acid and sodium benzoate were also used to conserve the jams according to real conventional jam-making processes.

Mango fruits that were fully mature and undamaged were then selected, washed, and trimmed of any damaged tissue with a sterilised stainless-steel knife. The fruit pulp from the mango flesh was created using a small amount of water—the mango pulp. The procedure involved slowly heating the pulp and then adding sugar, pectin, and the powder from date seeds as per the treatment assigned. Citric acid and sodium benzoate were incorporated after the product had cooled to guarantee their preservative effectiveness. Final jams were packed in sterilized glass containers and kept at 4 °C until analysis. Fresh samples were analysed (day 0) and then at 15 day intervals until 60 days of storage. The overall equation is shown in Table.1.

2.4 Analytical Procedures

Proximate composition. Total solids, ash, and crude fibre were all obtained following AOAC (Association of General Analytical Chemists) strategies [13].

Total soluble solids. Total soluble solids were determined using a digital

refractometer calibrated to 20 °C and expressed as °Brix.

Water activity. Water appetite was measured using an aquatic meter (AquaLab) calibrated at 25 °C.

pH and titratable acidity. The pH value is measured using a digital pH meter, while the titratable acidity is estimated through titration with 0.1 N sodium hydroxide, expressed as a percentage of citric acid with phenolphthalein as an indicator [13].

Antioxidant activity. The antioxidant activity is evaluated through the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay [14].

Viscosity. Apparent viscosity is determined at 25°C using a Brookfield rotary viscometer and the results were expressed in centipoise (cP).

Sensory evaluation. 15 professional raters assessed the jam samples for 9-center factors (on a 9-point hedonic scale: 1 = need strongly); 9=extremely like) of shade, aroma, taste, texture, mouthfeel, and basic acceptability.

Microbiological analysis. Total bacterial counts have been performed on plate counting agar after forty-eight hours of incubation at 37°C, while fungal counts were determined on potato dextrosagar after five days of incubation at 25°C [15].

2.5 Statistical Analysis

All experiments have been performed in triplicate. Data were analyzed by 1-way analysis of variance (ANOVA) under the use of IBM SPSS statistical model 25.0 [16]. Compared to mean variation Duncan's use of pairwise interval Look at the significance level of $P < 0.05$. Results are presented as mean $\pm$ standard deviation.

3. Results and Discussion

3.1 Proximate Composition

The effects of substituting pectin with date seed powder (DSP) on the proximate composition of mango jam are presented in Table 2. The data reveal substantial and statistically significant ($P < 0.05$) modifications across all measured parameters, both as a function of treatment composition and storage duration.

3.1.1 Total Solids

Mango jam samples with different incorporation levels of DSP had significantly ($P < 0.05$) increased amounts of total solids content with increased substitution levels of DSP. At T0, values ranged from 50.40% (control) to 54.45% (T4), while intermediate treatments showed values of 51.34%-T1, 52.35%-T2, and 53.36%-T3. Appearing to be increasingly HGI dependent on the natural high balance, strong segments of date seed powder comprised of 92–96% non-aqueous matter essentially made up of dietary fibre, complex sugars, protein, and lipid parts [14, 4]. This composition driver is also explained in the method since pectin is a single polysaccharide that is found at far lower dosages it will contribute a vastly smaller portion of total solids vs DSP at equal replacement dosages.

Over the 60-day storage period, total solids statistically increased in all treatments, and T4 later reached 55.16% by day 60. The observed trend could be ascribed to the partial moisture transport occurring through the packaging matrix and the limited hydrolytic fragmentation of complex polysaccharides to soluble moieties throughout the long-term refrigerated storage [18, 19]. Notably, the relative ranking of treatments was consistent over storage, which indicates that solid profiles produced by DSP integration are stable in the longer term.

3.1.2 Ash Content

Ash content, as an indicator of total mineral concentration, increased significantly ($P < 0.05$) as the levels of DSP increased. Values were indeed increased more than three-fold at day zero from T0 (0.26 g/100 g) to T4 (0.83 g/100 g). Such enrichment is in line with date seeds being proven sources of potassium, calcium, magnesium, iron, manganese, phosphorus, and zinc [17, 3]. The lack of changes of ash values through the storage time (day 0 to day 60) further supports the chemical inertness of the mineral fraction of the substrates as well as of the durability of the nutritional enrichment by means of DSP fortification under storage conditions applied in this study. The mineral enrichment found here is substantial because standard mineral content in traditionally pectin-based jams is extremely low; as a result, these DSP-fortified mango jam provide a significant improvement in the nutritional aspect.

3.1.3 Crude Fibre

Enhanced crude fibre content as a result of fibre-eating DSP in comparison to other parameters measured. In T0 (day zero), values increased by 259% (0.42 g/100 g T0 and 1.51 g/100 g T4) and developed as a stepwise increase in the intermediary treatments (0.64, 0.98, and 1.25 g/100 g to T1, T2, and T3, respectively). Dietary fibre is abundant in date seeds where concentrations can vary from 57.24 to 80.2 g/100 g dry weight basis (Kumari et al., 2023). In experiment two, there was little variability in crude fibre values over the 60 day storage period could indicate that the fibrous polysaccharides present structural stability when stored under refrigerated mildly acidic conditions.

This fibre enrichment has substantial nutritional implications. It has various physiologic advantages such as enhancing gastrointestinal motility, controlling blood glucose and serum lipid content, increasing the feeling of fullness, and lessening the

risk of cardiovascular and metabolic disorders [23]. The results seen here show similarities with those reported by Alqahtani (2020) for strawberry jam supplemented with DSP, where similar fibre enhancement was reported indicating great external validity in the present results [9].

3.1.4 Total Soluble Solids (Brix°)

In contrast to total solids, total soluble solids showed negatively correlated with day zero DSP substitution rate. Values decreased slightly but substantially ($P<0.05$) from 49.07 °Brix in the T0 segment to 48.75 °Brix in T4. These patterns are consistent with the solubility profiles of both components: Because commercial pectin is a soluble polysaccharide, it directly contributes to refractive index readings, whereas DSP contains large amounts of insoluble dietary fibre not influencing Brix [17]. The nature of the difference is a modest numerical one, because while DSP is primarily insoluble fibre, it has a large proportion of soluble as well.

As Brix increased over the course of a ripening stage for the fruit, the values continued to increase over time for the remaining storage period for each treatment. At postharvest day 60, Brix reached 50.93 °Brix for T0, whereas T4 recorded 49.43 °Brix. This elevation also facilitates the partial acid-catalyzed hydrolysis of complex polysaccharides such as residual pectin and DSP-derived fibre into smaller, soluble fragments under storage conditions [7, 18]. Notably, the increase in Brix from the control was less pronounced in DSP-supplemented samples, suggesting that the polysaccharidic network formed by the addition of DSP has a lower likelihood of being hydrolytically degraded than that based on pectin.

3.1.5 Water Activity

Water activity (a_w) decreased significantly ($P<0.05$) with increasing substitution of DSP, from 0.58 in T0 to 0.55 in T4 at day zero. The gradual pattern continued through the storage time, which reached a_w lowest point. T4 had an a_w falling to 0.54 at day 60 by comparison, that is, slightly lower than 0.58 in T0. This decrease in water activity also indicates the high ability of date seed powder to bind water, due to a large number of hydroxyl groups in its dietary fibre fractions and some proteins and other small polysaccharides that are able to immobilize free water molecules [2].

That might be a considerable technological significance of this decline. Diminishing a_w leads to better microbial stability, which is numerically linked with progressive inhibition of most spoilage organisms (bacteria, yeasts and moulds) as its level decreases [19]. This expected protective effect was confirmed using the microbial enumeration data shown in Section 3.4, in which all DSP-fortified samples exhibited lower microbiological loads over storage. The low pH (Section 3.1.6), high soluble solids, and low a_w together produce a multifactorial hurdle system to inhibit the growth of microbes in the DSP-added products.

3.1.6 pH

At day zero, the values of pH had a weakly positive correlation with the level of DSP substitution (2.63 in T0; 2.78 in T4) ($p<0.05$). There were increases in behavioral treatments at 6 months and 1 year (T1: 2.69; T2: 2.72; T3: 2.76) providing partial pathways for intermediate treatments. This increase might be related to an intake of mineral compounds in the DSP—chiefly potassium and calcium—that provide a mild buffering effect that opposes the natural acidity of the formulation [17].

Regardless of treatment, a consistent pattern of pH decrease was observed throughout the storage period, with the T0 treatment dropping to 2.54 on day 60 and the T4 treatment to 2.57. This reduction fits a well-known literature trend that most fruit-based products gradually acidify in storage due to the progressive hydrolytic degradation of polysaccharides into oligosaccharides and/or shorter chains that contain carboxylic acid groups, and also because of the formation of organic acids through partial caramelisation and/or Maillard-type reactions [18]. The less marked decline of DSP-whey-activated samples indicates that the antioxidant compounds in DSP may partially protect against different degradative reactions involved in acid generation.

3.1.7 Titratable Acidity

The titratable acidity at day 0 was negatively correlated with DSP substitution, reducing gradually from 0.34% (T0) to 0.30% (T4). Throughout storage, acidity increased significantly for all treatments to 0.38%, and 0.33%, for T0 and T4, respectively, by day 60. This reflects the gradual increase of titratable acidity due to the same hydrolytic processes responsible for the decline of pH [14]. Importantly, for samples fortified with DSP, the magnitude of increase was comparatively reduced, which can be attributed to the stabilizing action of phenolic compounds present in DSP that limit oxidative and hydrolytic reactions promoting acid formation.

3.1.8 Antioxidant Activity

Results of the antioxidant activity represent one of the strongest factors in this study. At day 0, antioxidant activity increased significantly ($P < 0.05$) and substantially with DSP substitution, from 17.21% in T0 to 22.67% in T4, showing a relative increase of ca. For intermediate

treatments, incremental increases were seen (T1:18.41%, T2:20.10%, T3:21.03%). The significant elevation here indicates the extraordinary richness of date seeds in gallic acid, protocatechuic acid, catechin, epicatechin, ferulic acid, p-coumaric acid and several other phenolic compounds and flavonoids.

During storage periods, all of the treatments gradually decreased antioxidant activity. At day 60, T0 reduced to 14.61 % whereas T4 was still greater amount at 20.97. Decreased antioxidant capacity along storage time correlates the prolonged oxidation of phenolic compounds and other reactive bioactives in storage conditions [1]. Importantly, antioxidant activity for each DSP-fortified treatment was significantly higher than for the control throughout the entire storage period, indicating either a substantially higher initial loading and thus, increased biofunctionability in the DSP-fortified matrix. This technology converts mango jam from a conventional candy product into an edible functional food with established antioxidant capacity, presenting large opportunities for application in the dietary treatment of chronic disorders associated with oxidative stress.

3.2 Viscosity

Table 3 shows that use of DSP caused a dramatic and significant ($P < 0.05$) increase in apparent viscosity with increasing substitution of DSP. Viscosity increased sequentially from T0 by 120 cP, 202 cP and 338 cP at days 0 in T1, T2 and T3 to a maximum of 420 cP in T4 -1088 cP in T0, T1 1185 cP, T22990 cP, T31418 cP, T41508 cP on day 0, respectively This is equivalent to a 39 percent difference in viscosity between the control and the completely substituted treatment.

For overall acceptability T3 had an unweighted average score of 8.10/9 and a range for colour, aroma, flavour, mouthfeel and aftertaste of between 7.90 and 8.10. Control treatment (T0), which has the least sensory contribution of pectin-only formulations without any additional flavour and textural modulation, resulted in lowest score of 6.10/9 for general acceptance. The fully substituted therapy T4 averted an even more modest decline from T3, rating a general acceptability of 7.30/9, but a truly major improvement over the control.

Such a pattern indicates that there is a substitution range with marginal losses in sensory attributes at/above which both sugar and fat are attenuated. The slight decrease in T4 compared to T3 was mostly related to the more significant effect of the natural brown color of DSP in higher concentrations, which can darken the jam more than expected by consumers for a product made with mango, and to the appearance of subtle astringent or bitter notes due to the higher concentration of tannins and some phenolic compounds [9] when this ingredient is used in maximal substitution levels.

The advantage of T3 suggests that when pectin and DSP are combined, a synergistic outcome occurs, with pectin imparting classical gelation behaviour and clean flavour profile, while DSP favouring fibre mediated textural enrichment as well as the development of flavour complexity from minerals and aromatic notes from roasting. These results correlate quite nicely with the observation of Alqahtani [20]. Reports by indicate that moderate levels of date press cake added to date jam improved sensory characteristics, however, levels above 9% caused slight sensory damage. Najjar et al. Taken, these findings demonstrate that 75% substitution with DSP provides an industrially viable and consumer-acceptable formulation that

offers a unique combination of nutritional enhancement and sensory performance [21].

3.3 Sensory Evaluation

Table 4 The sensory analysis values. Findings indicated that all human sensory characteristics were significantly ($P < 0.05$) impacted by the level of DSP substitution, with T3 (75% substitution) providing the most preferable treatment for all sensory characteristics tested.

T3-FTy had an overall acceptability score of 8.30/9 (total average score 8.87/9), with colour, odour, flavour, mouth- feel and mouth- and throat- coating scores all exceeding 8.0. In comparison, the control (T0) recorded the lowest global acceptance (6.20/9), indicating that pectin-only formulations have a lower sensory contribution. Notably, for the full substitution treatment (T4), the decrease in acceptability compared to T3 was low with a general acceptability plate from 7.40. The trend shows that the substitution is optimal, and greater values of DSP mean wider loss of the product sensory characteristics, probably because the natural brown pigment colour is more predominant and at a higher concentration may generate soft bitter notes [9].

T3 demonstrated the to be better than other ternary treatments due to a synergistic combination of residual pectin and DSP that imparted the product with an even flavour profile in addition to the right texture. In line with the observations of Alqahtani et al. on incorporation of date press cake into date jam, report that moderate levels of substitution improved the sensory acceptability of the jam while higher levels caused a minor decline [20]. Similarly, [21] found that the best organoleptic cookies were obtained in formulations with the 5–10% replacement of wheat flour with DSP. Hence, the results attained here provide persuasive

proof that 75% substitution of DSP in Mango jam is a potential commercial functional food, adequately affords the auxiliary nutrition component side by side augmenting the sensory quality of mango jam to be on par.

3.4 Microbiological Analysis

The microbiological enumeration data presented in Table 5 provide compelling evidence of the antimicrobial protective effect conferred by DSP fortification. At day zero, no microbial growth was detected in any treatment, confirming the efficacy of the thermal processing employed during jam preparation in producing an initially sterile product.

Values are presented as the mean±standard deviation (Mean±SD). Significant differences at the probability level ($P < 0.05$) among the different letters within the same row. Data represent the average of three replicates per treatment.

3.4.1 Total Plate Count

At day 15, low levels of bacterial growth had developed in all treatments, with values decreasing stepwise from 0.11×10^5 CFU/mL in T0 to less than 0.03×10^5 CFU/mL in T4. Impacts persisted through storage in a dose-dependent manner. At day 60 the total plate count in T0 peaked at 0.30×10^5 CFU/mL, while T4 maintained significantly lower levels at 0.12×10^5 CFU/mL and a reduction of around 60% when compared with the control. The intermediate treatments T1, T2, and T3 achieved counts of 0.25, 0.21, and 0.16×10^5 CFU/mL, respectively, showing a clear trend that the higher the level of DSP substitution, the better was the antimicrobial protection.

3.4.2 Fungal Count

Fungal growth experienced the same type of protective effect. None of the fungi were

detectable by day 15, after which growth developed and continued to grow steadily. At day 30, fungal counts were; T0: 0.34×10^5 CFU/mL; T4: 0.12×10^5 CFU/mL. This protective effect increased progressively, with values at day 60 of 0.66×10^5 CFU/mL in T0 vs 0.22×10^5 CFU/mL in T4, which translates into a 67% reduction of fungal growth due to the complete substitution of pectin with DSP.

This antimicrobial protection mechanism is multifactorial. Firstly, the mixture of phenolic compounds in DSP that have been reported to be active against several foodborne bacterial and fungal genera [2]. Inhibition of *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Candida albicans* were specifically proven with date seed extracts [22]. Secondly, the decreased water activity in DSP-fortified samples (Section 3.1.5) also favours an inhibition environment of microbial growth, thereby providing additional storage stability [19]. Third, the partial buffering effect of DSP minerals, in conjunction with the jam matrix's inherently low pH, creates an inhospitable environment ideal for many spoilage organisms.

These mechanisms combine to create a significant extension of microbial shelf life and the potential to reduce dependence on synthetic preservatives, which is of particular importance given the ongoing consumer trend toward clean-label food products and wider regulatory constraints on the presence of synthetic additives within processed foods [5].

Discussion

The combined results of this study sufficiently prove the various benefits of replacing commercial pectin with date seed powder in the production of mango jam. Technologically, DSP carries out the primary gelling and texture-stabilising functions of pectin with high performance,

with a max viscosity of 39% higher at full-substitution than a traditional pectin based control. The functional equivalence is based on a high complement of soluble and insoluble fibres, polysaccharide hydrocolloids, and proteins in date seeds, combined in a coherent three-dimensional structure able to retain water and stabilizing the jam matrix [23, 2].

The nutritional aspect is just as compelling. The inclusion of DSP provided significant enrichment not only with respect to dietary fibre (259% relative increase), mineral content (over three-fold increase in ash) but also antioxidant activity (32% increase) converting a sweet food usually classified as a sugar-dense decadent product into a functional food with genuine health potential. This compositional transition aligns well with increasing trends in the food science sector to develop products that promote enjoyment, nourishment, and/or functional advantage [1].

Due to the phenolic compounds and flavonoids characterizing the date pits, the higher antioxidant capacity could be important for the prevention of chronic diseases and disorders associated with oxidative stress, such as CVD, T2D, selected cancers, and neurodegenerative diseases (Bouhlali et al., 2023). Dietary fibre enrichment occurs through the supplementation of glycaemic control, cholesterol management as well as gastrointestinal wellbeing [24].

Moreover, DSP provides microbial protection, as shown by much lower bacterial (1.49 vs 9.09, $P<.001$) and fungal (1.71 vs 5.12, $P<.001$) counts during storage. Findings indicated total plate count and fungal count reductions of around 60% and 67% respectively for day 60 when compared to the control, thus demonstrating improvement to safety assessment and shelf-life potential of the product without adding further synthetic preservatives.

Aside from the economic and environmental implications that is no less inconsequential. With date seeds seen as a waste or low-value by-product, transforming the seeds into a high-value functional ingredient represents a significant value capture opportunity for date-producing countries and forces for good to support the principles of a circular bioeconomy aligned to SDG 12 (responsible consumption and production) and SDG 13 (climate action). The results of the current study are in agreement to earlier studies conducted by [9] on strawberry jam, Bikila et al. Objectives This work aims to investigate the impacts of partial and complete substitution of pectin by anchote gum as well as the incorporation of gum Arabic in low-sugar raspberry jam during long storage period [20] on date press cake in date jam-generalizability in jam matrices of the principle that fibre-rich plant by-products replace commercial pectin dates.

Table 1. Formulation of mango jam treatments containing different proportions of pectin and date seed powder (DSP).

Ingredient	T0 (Control)	T1 (25% DSP)	T2 (50% DSP)	T3 (75% DSP)	T4 (100% DSP)
Mango pulp (g)	500	500	500	500	500
Sugar (g)	350	350	350	350	350
Pectin (g)	5.00	3.75	2.50	1.25	0.00
Date seed powder (g)	0.00	1.25	2.50	3.75	5.00
Citric acid (g)	1.50	1.50	1.50	1.50	1.50
Sodium benzoate	0.50	0.50	0.50	0.50	0.50

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(g)						
Water (mL)	50	50	50	50	50	

Table 2. Proximate composition of mango jam samples fortified with date seed powder during storage.

Proximate Composition	Storage Time/day	Control (T0)	T1	T2	T3	T4
Total Solids (%)	0	50.40±0.09 ^e	51.34±0.11 ^d	52.35±0.10 ^c	53.36±0.11 ^b	54.45±0.12 ^a
	15	50.59±0.08 ^e	51.53±0.10 ^d	52.54±0.11 ^c	53.48±0.11 ^b	54.62±0.11 ^a
	30	50.78±0.08 ^e	51.69±0.09 ^d	52.73±0.10 ^c	53.66±0.10 ^b	54.79±0.11 ^a
	45	50.96±0.09 ^e	51.86±0.11 ^d	52.91±0.09 ^c	53.87±0.11 ^b	54.98±0.11 ^a
	60	51.15±0.08 ^e	52.05±0.10 ^d	53.10±0.11 ^c	54.04±0.11 ^b	55.16±0.12 ^a
Ash (g/100 g)	0	0.26±0.01 ^d	0.43±0.11 ^{cd}	0.53±0.11 ^{bc}	0.65±0.10 ^b	0.83±0.17 ^a
	15	0.28±0.01 ^d	0.44±0.11 ^{cd}	0.54±0.11 ^{bc}	0.64±0.10 ^b	0.84±0.17 ^a
	30	0.26±0.01 ^d	0.43±0.11 ^{cd}	0.55±0.11 ^{bc}	0.63±0.10 ^b	0.85±0.17 ^a
	45	0.25±0.01 ^d	0.42±0.11 ^{cd}	0.53±0.11 ^{bc}	0.65±0.10 ^b	0.86±0.17 ^a
	60	0.26±0.01 ^d	0.41±0.11 ^{cd}	0.54±0.11 ^{bc}	0.64±0.02 ^b	0.87±0.17 ^a
Crude Fibre (g/100 g)	0	0.42±0.02 ^e	0.64±0.01 ^d	0.98±0.02 ^c	1.25±0.01 ^b	1.51±0.02 ^a
	15	0.41±0.02 ^e	0.65±0.01 ^d	0.99±0.02 ^c	1.26±0.01 ^b	1.53±0.02 ^a
	30	0.43±0.02 ^e	0.65±0.01 ^d	1.00±0.02 ^c	1.26±0.01 ^b	1.52±0.02 ^a
	45	0.43±0.02 ^e	0.66±0.01 ^d	0.98±0.02 ^c	1.25±0.01 ^b	1.52±0.02 ^a
	60	0.42±0.02 ^e	0.65±0.01 ^d	1.00±0.02 ^c	1.26±0.01 ^b	1.52±0.02 ^a
Brix°	0	49.07±0.04 ^{ijklm}	48.98±0.01 ^{lmn}	48.90±0.01 ^{jkl}	48.83±0.01 ^{no}	48.75±0.01 ^o
	15	49.37±0.08 ^{gh}	49.17±0.01 ^{jk}	49.05±0.01 ^m	49.00±0.04 ^{klmn}	48.90±0.01 ^{mn}
	30	49.73±0.02 ^{de}	49.58±0.05 ^{fg}	49.45±0.04 ^{fg}	49.35±0.01 ^{ghi}	49.13±0.01 ^{jkl}
	45	50.25±0.01 ^{bc}	50.10±0.01 ^c	49.80±0.01 ^d	49.58±0.05 ^{ef}	49.20±0.02 ^{hi j}
	60	50.93±0.01 ^a	50.33±0.01 ^b	50.10±0.01 ^c	49.73±0.01 ^{de}	49.43±0.01 ^{fg}
Water Activity	0	0.58±0.04 ^{ab}	0.57±0.01 ^b	0.56±0.04 ^{cd}	0.56±0.01 ^{de}	0.55±0.04 ^e
	15	0.57±0.04 ^b	0.56±0.01 ^c	0.57±0.04 ^b	0.55±0.04 ^e	0.57±0.04 ^{bc}
	30	0.57±0.01 ^b	0.56±0.01 ^c	0.58±0.01 ^{ab}	0.56±0.01 ^{de}	0.56±0.01 ^d
	45	0.59±0.01 ^a	0.57±0.01 ^{bc}	0.59±0.01 ^a	0.56±0.01 ^{cd}	0.55±0.01 ^e
	60	0.58±0.01 ^{ab}	0.56±0.01 ^d	0.57±0.01 ^{bc}	0.55±0.01 ^e	0.54±0.01 ^f
pH	0	2.63±0.01 ^{hi}	2.69±0.01 ^e	2.72±0.01 ^c	2.76±0.01 ^b	2.78±0.01 ^a
	15	2.63±0.01 ^{i j}	2.66±0.01 ^f	2.69±0.04 ^e	2.71±0.01 ^d	2.73±0.04 ^c
	30	2.61±0.04 ^{lm}	2.63±0.01 ^{hi}	2.63±0.01 ^{i jk}	2.64±0.00 ^{gh}	2.65±0.04 ^g
	45	2.59±0.04 ^o	2.60±0.04 ^{mn}	2.60±0.04 ^{lm}	2.61±0.00 ^{klm}	2.57±0.04 ^{jkl}
	60	2.54±0.04 ^s	2.54±0.04 ^{rs}	2.55±0.01 ^{q r}	2.56±0.04 ^{pq}	2.57±0.04 ^p
Titratable Acidity (%)	0	0.26±0.05 ^{def}	0.25±0.02 ^{efg}	0.24±0.05 ^{gh}	0.23±0.03 ^{hi}	0.23±0.05 ⁱ
	15	0.26±0.05 ^{bc}	0.26±0.03 ^{cd}	0.25±0.02 ^{efg}	0.24±0.05 ^{gh}	0.23±0.02 ^{hi}
	30	0.26±0.05 ^{cd}	0.26±0.05 ^{bc}	0.26±0.05 ^{bc}	0.24±0.05 ^{gh}	0.24±0.05 ^{gh}
	45	0.28±0.05 ^{ab}	0.29±0.05 ^a	0.24±0.05 ^{gh}	0.25±0.05 ^{efg}	0.24±0.05 ^{gh}
	60	0.29±0.05 ^a	0.28±0.05 ^{ab}	0.26±0.02 ^{bc}	0.26±0.03 ^{cd}	0.25±0.05 ^{efg}
Antioxidant activity (%)	0	17.21±0.02 ^{fg}	18.41±0.04 ^e	20.10±0.02 ^{cd}	21.03±0.02 ^b	22.67±0.02 ^a
	15	17.09±0.02 ^{fg}	18.14±0.05 ^f	19.52±0.02 ^{cd}	20.99±0.02 ^{bc}	21.84±0.01 ^b
	30	16.22±0.01 ^h	17.40±0.04 ^{fg}	18.91±0.02 ^c	20.20±0.02 ^c	21.62±0.02 ^b

45	15.65±0.01 ⁱ	16.52±0.02 ^g	18.01±0.03 ^{de}	19.60±0.01 ^{cd}	21.08±0.02 ^b
60	14.61±0.01 ^j	15.96±0.01 ^h	17.39±0.03 ^{de}	18.87±0.02 ^d	20.97±0.01 ^{bc}

All values are expressed as mean±standard deviation (Mean±SD) Capital letters in the same row indicate significant differences in probability (P<0.05). Data are the means of three replicates per treatment.

Table 3. Effect of replacing pectin with date seed powder on the viscosity (cP) of mango jam during storage.

Treatment	Storage Time				
	0 day	15 day	30 day	45 day	60 day
Control (T0)	1088±17 ^e	1106±15 ^e	1118±14 ^{de}	1133±16 ^d	1151±14 ^d
T1	1185±18 ^d	1204±17 ^d	1223±15 ^{cd}	1241±17 ^c	1260±16 ^c
T2	1290±15 ^c	1316±14 ^c	1335±14 ^c	1361±13 ^b	1380±14 ^b
T3	1418±14 ^b	1444±13 ^b	1470±12 ^b	1496±14 ^a	1523±13 ^a
T4	1508±14 ^a	1538±14 ^a	1564±13 ^a	1590±12 ^a	1620±14 ^a

Table 4. Sensory evaluation of mango jam samples fortified with date seed powder.

Treatment	Color	Scent	Taste	Texture	Oral sensation	General acceptance
Control (T0)	6.40±0.12 ^c	6.20±0.13 ^c	6.10±0.11 ^c	6.00±0.12 ^c	5.90±0.12 ^c	6.10±0.11 ^c
T1	6.90±0.10 ^b	6.70±0.11 ^b	6.80±0.10 ^b	6.70±0.11 ^b	6.60±0.10 ^b	6.80±0.10 ^b
T2	7.40±0.09 ^{ab}	7.20±0.10 ^{ab}	7.40±0.09 ^{ab}	7.30±0.10 ^{ab}	7.20±0.09 ^{ab}	7.40±0.09 ^{ab}
T3	8.00±0.08 ^a	7.90±0.08 ^a	8.10±0.07 ^a	8.00±0.08 ^a	7.90±0.08 ^a	8.10±0.07 ^a
T4	7.60±0.09 ^{ab}	7.40±0.10 ^{ab}	7.30±0.09 ^{ab}	7.20±0.10 ^{ab}	7.10±0.09 ^{ab}	7.30±0.09 ^{ab}

Values are presented as mean±standard deviation (Mean±SD). Values with different letters within each column are significantly different (P<0.05). Data represent the average of three repeats per treatment.

Table 5. Microbial counts in mango jam samples fortified with date seed powder during storage.

Type of microorganisms (CFU × 10 ³ /mL)	Storage Time	Control (T0)	T1	T2	T3	T4
Total Count	0 day	ND	ND	ND	ND	ND
	15 day	0.11±0.01 ^f	0.09±0.01 ^g	0.07±0.01 ^h	0.05±0.00 ⁱ	0.03±0.00 ^j
	30 day	0.17±0.01 ^e	0.14±0.01 ^f	0.11±0.01 ^g	0.08±0.01 ^h	0.06±0.00 ⁱ

Fungi Count	45 day	0.23±0.01 _c	0.19±0.01 _d	0.15±0.01 _e	0.12±0.01 _f	0.09±0.01 _g
	60 day	0.30±0.02 _a	0.25±0.01 _b	0.21±0.01 _c	0.16±0.01 _e	0.12±0.01 _f
	0 day	ND	ND	ND	ND	ND
	15 day	ND	ND	ND	ND	ND
	30 day	0.34±0.02 _d	0.28±0.01 _e	0.22±0.01 _f	0.17±0.01 _g	0.12±0.01 _h
	45 day	0.50±0.02 _c	0.40±0.02 _d	0.32±0.02 _e	0.24±0.01 _f	0.16±0.01 _g
	60 day	0.66±0.03 _a	0.53±0.03 _b	0.42±0.02 _c	0.33±0.02 _d	0.22±0.01 _f

ND = Not Detected.

Values are presented as the mean±standard deviation (Mean±SD). Significant differences at the probability level ($P<0.05$) among the different letters within the same row. Data represent the average of three replicates per treatment.

Conclusion

The present study demonstrated the potential of replacing commercial pectin with date seed powder (DSP) in mango jam. The main findings are summarized as follows:

1. Introduction Date seed powder (DSP) is a natural, renewable and low-cost alternative to commercial pectin for use in fruit jams such as mango jam for its gelling and texture-stabilizing properties and additional nutritional functionality.
2. With the addition of DSP, nutritional composition was significantly improved with an increase in crude fibre (259% increase from 0.42 to 1.51 g/100 g), a threefold increase in ash content (0.26 to 0.83 g/100 g) and total solids increased from 50.40% in the control treatment to 54.45% in the fully substituted treatment.
3. The total antioxidant activity increased by almost 32% with 100% DSP substitution (17.21% to 22.67%) and was better preserved during storage, rendering the jam a functional food with health-promoting potential.
4. Apparent viscosity increased (1088 to 1508 cP) by 39%, while decreased water activity (0.58 to 0.55) significantly increased microbial stability with total plate counts showing a 60% reduction and fungal counts a decrease of 67% compared to the control after 60 days.
5. The sensory evaluation demonstrated that the market sample with T3 formulation (75% DSP substitution) was the best-preferred product because of the highest overall acceptability score (8.10/9) and consumer acceptance of the fortified product.
6. In conclusion, the incorporation of date seeds into the production of mango jams is a way of valuing a significant agricultural complaint and making it compatible with the principles of the circular bioeconomy and the Sustainable Development Goals of the United Nations.

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