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Development and shelf-life evaluation of mango-blended corn milk yogurt

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ABSTRACT

Corn milk, made from *Zea mays*, is a popular non-dairy option for lactose-intolerant individuals, rich in vitamins and low in saturated fats. Probiotic corn-based products, especially yogurt, are scarce in the market. Combining the intake of yogurt and fruit could provide probiotics, prebiotics, vitamins and minerals that have the potential to exert synergistic effects on consumer health along with delicious taste. The present study introduced a probiotic mango-blended corn milk yogurt, combining yogurt and mango benefits to provide probiotics, prebiotics, vitamins, and minerals. The development of probiotic mango-blended corn milk yogurt addresses the gap in corn-based probiotic products, offering a flavorful and healthful choice. Mango-blended milk yogurt was used as a control. Two formulations were created using probiotic cultures: *Streptococcus thermophilus* with *Lactobacillus casei* and *Streptococcus thermophilus* with *Lactobacillus delbrueckii*. Comparative analysis revealed significant variations in physicochemical properties, with corn milk yogurt exhibiting distinct characteristics, including lower fat and protein content but higher titratable acidity and lower pH levels during storage. Sensory evaluations shown the superior acceptability of *S. thermophilus* with *Lactobacillus casei* corn milk yogurt samples, underscoring its appeal to consumers. The study also demonstrated the microbiological stability of corn milk yogurt, with no yeast, mould, or coliform growth observed during three weeks of refrigeration. Probiotic counts remained high, ensuring the retention of health benefits throughout storage. This novel product demonstrates both nutritional importance and sensory appeal, providing a promising foundation for future developments in the functional food market.

Key words: Probiotic, yogurt, shelf life, sensory, functional food.

INTRODUCTION

Mango (*Mangifera indica* L.), a member of the family Anacardiaceae, stands as India's most important commercially grown fruit crop, accounting for nearly 50% of global mango production (Pong *et al*., 1). Among the myriad varieties, the Safeda mango from Andhra Pradesh is particularly valued for its early-season availability, extended shelf life, and high nutrient content, making it a versatile ingredient in various food products. Its sweet, juicy flesh with a hint of sourness, complemented by high levels of vitamins and antioxidants (Thakur *et al*., 2) renders it a promising addition to modern functional foods like fruit-flavoured yogurts, which are growing in popularity.

Yogurt is widely regarded as a probiotic functional food due to its lactic acid bacteria that provide therapeutic benefits, including enhanced nutrient digestibility and antimicrobial activity. Incorporating fruits like mango into yogurt enhances its sensory and nutritional profiles, enriching it with additional vitamins, minerals, antioxidants, and prebiotic fibres. Previous research has demonstrated that combining fruit and yogurt can synergistically improve the viability of probiotics, ensuring enhanced health benefits (Nasution and Wahyuni, 3). However, while dairy-based mango-flavoured yogurts are common in the market, studies focusing on mango fortification in plant-based yogurt, particularly with corn milk, remain sparse.

Corn (*Zea mays*), India's third most important cereal crop, offers immense potential as a plant-based milk alternative. It is nutritionally rich, containing essential vitamins, antioxidants, and bioactive compounds such as lutein and zeaxanthin, contributing to health benefits like reducing the risk of certain chronic diseases. Corn milk has emerged as a promising substitute for animal milk, especially for lactose-intolerant, vegan, and health-conscious individuals. It is low in fat, free of gluten, and boasts a pleasant taste and aroma, making it suitable for fermented products like yogurt (Supavititpatana *et al*., 4). Despite these advantages, the development of fermented corn milk products remains limited, highlighting a notable research gap in the field.

The present study aims to address these gaps by developing a mango-blended corn milk yogurt as a functional food product using probiotic cultures. This innovation combines mango's sensory and nutritional appeal with corn milk's probiotic, prebiotic,

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and functional properties, offering a plant-based alternative to conventional dairy products (Aydar *et al*., 5). Unlike commercially available cow milk-based fruit yogurts, this product is tailored to meet the needs of lactose-intolerant and vegan consumers while maintaining high probiotic viability and organoleptic quality. Therefore, the present study involves the development of mango-blended corn milk-based yogurt. Two formulations were created using probiotic cultures: *Streptococcus thermophilus* with *Lactobacillus casei* and *Streptococcus thermophilus* with *Lactobacillus delbrueckii*. Physicochemical and organoleptic attributes of corn milk-based yogurt samples were assessed weekly during three weeks of storage. Survival of probiotic cultures and the microbial load was accessed in yogurt samples to adjudge better probiotic combinations for mango blended corn milk yogurt. This study seeks to provide a sustainable and health-focused alternative to conventional dairy-based yogurts, thus contributing to advancements in the functional food industry.

MATERIALS AND METHODS

Pure culture of *Streptococcus salivarius ssp. thermophilus* (ATCC 19258), *Lactobacillus casei* (ATCC 4356) and *Lactobacillus delbrueckii* (ATCC 7830) were procured from HiMedia. For culture revival, the vial was opened, and the lyophilized culture pellet was rehydrated using 5-6 ml pre-sterilized *Streptococcus thermophilus* Agar and Mann Rogosa and Sharpe (MRS) broth for *S. thermophilus* and *Lactobacillus* sp., respectively. For pure culture, rehydrated culture broth was aseptically streaked on their respective agar and incubated at 37°C. The colony grew after 24 h and was further maintained on refrigerated slants.

Whole cream milk was purchased from the market with predetermined fat (6%) and SNF (9.0%). Corn cv. Sugarbaby and mango cv. Safeda were procured from the local market of Hisar. Corn cobs were husked, and silk was removed and washed. Kernels were separated and soaked in water in a ratio of 1:2 (corn kernels to water) for two h. Corn kernels and water mix were heated at 95°C for 10 min, cooled to room temperature and blended to produce a solution. The solution was then filtered through a clean muslin cloth. Corn milk was prepared by blending corn exudate and whole cream milk in a ratio of 60:40.

Full-cream milk procured from the market was boiled in a stainless steel vessel for 10 to 15 min. and then allowed to cool at room temperature. Two variations each of corn milk yogurt (Fig. 1) and milk yogurt were prepared by inoculating the cooled milk with starter culture combinations, *i.e.*, *S. thermophilus* & *L. casei* (1:1) and *S. thermophilus*

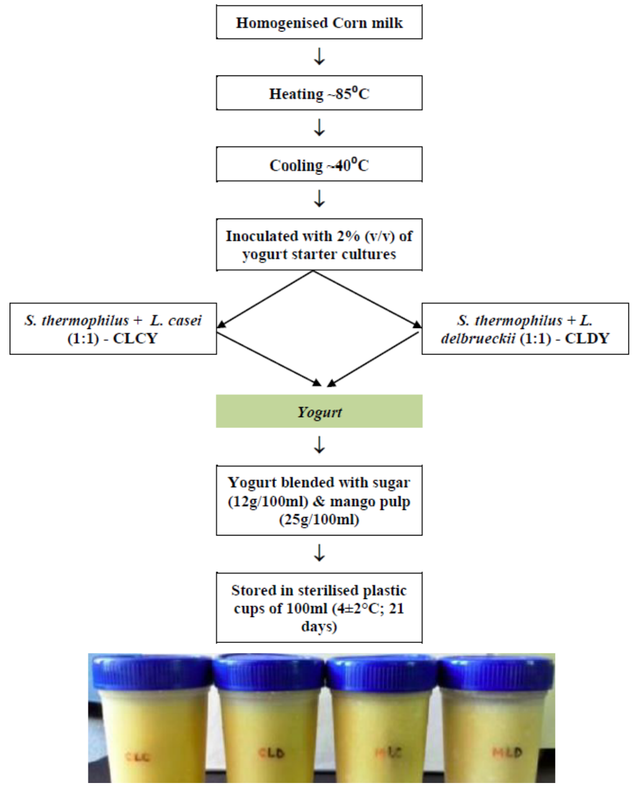

Fig. 1. Flow chart for the preparation of mango-blended corn milk yogurt.

Table 1: Mango blended milk and corn milk yogurt probiotic formulations:

Mango blend milk yogurt	Mango blend corn milk yogurt
S. thermophilus and *L. casei* (MLCY)	*S. thermophilus* and *L. casei* (CLCY)
S. thermophilus and *L. delbrueckii* (MLDY)	*S. thermophilus* and *L. delbrueckii* (CLDY)

& *L. delbrueckii* (1:1) separately. The vessels were covered with muslin cloth and a lid. The milk was then incubated at 37°C for 12 h. Corn milk yogurt and milk yogurt samples were blended with sugar @ 12 g/100 ml and mango pulp @ 25 g/100 ml (Table 1) as following:

1. Milk *S. thermophilus* with *L. casei* yogurt (MLCY).
2. Corn-milk *S. thermophilus* with *L. casei* yogurt (CLCY).
3. Milk *S. thermophilus* with *L. delbrueckii* yogurt (MLDY).
4. Corn-milk *S. thermophilus* with *L. delbrueckii* yogurt (CLDY).

The prepared yogurt samples were stored at refrigerated temperature (4 ± 2°C) for storage studies at weekly intervals for up to three weeks.

The pH of milk was determined by a digital pH meter (Elico India Ltd., using standard buffers pH 4.0 and 7.0). Titratable acidity (TTA) was determined by the NaOH method, crude protein by the Micro-Kjeldahl method and fat was estimated by the Rose-Gottlieb Method (Nielsen, 6). Sugar was determined by the method of Hulme and Narain (7), total carotenoids by Rodriguez-Amaya (8), total pectin as calcium pectate by Ranganna (9), ascorbic acid and total phenols by AOAC (10). Total soluble solids (TSS) of mango pulp were estimated by hand refractometer (0-32%) (Erma, Japan) and Water holding capacity (WHC) were estimated using the method by Lalou *et al.* (11). Probiotic count was estimated by pour plate method under anaerobic conditions at 37°C for 72 h. The serial dilution method estimated the Coliform, Yeast, and mold count on Violet Red Bile Agar and Potato Dextrose Agar (PDA). Sensory evaluation of mango blend corn milk yogurt variants was done by using 9-point Hedonic scale at weekly interval by a panel of 10 semi-trained judges. The products were evaluated on the basis of colour and appearance, taste, body and texture, aroma and flavour and overall acceptability. The overall acceptability was based on mean scores obtained from all the sensory characteristics.

The data were statistically analyzed using two-way analysis of variance (ANOVA) procedures in a completely randomized design with three replications. Statistical analysis was performed using the OPSTAT software version opstat1.exe (CCSHAU Hisar, India). A 5% level of significance was chosen to interpret the results after statistical analysis. Critical difference (CD) was calculated to find out the significance between the samples for each parameter.

RESULTS AND DISCUSSION

Pasteurized whole cream milk having predetermined fat (6%) and SNF (9.0%) was analyzed for pH (6.7), titratable acidity (0.11%) and protein content (3.34%). Corn milk prepared by blending corn extrudate and whole cream milk in a ratio of 60:40 was found to have acidity (0.19%), pH (6.89), crude protein (2.5%) and total carotenoids (1.6 mg/100g). All the above-mentioned parameters of milk samples were within the normal range. Mango fruit is well-known for its distinct flavour and scent. Mango has high β-carotene concentration, notable levels of ascorbic acid, total phenols, and quercetin (Pong *et al.,* 1). The fresh pulp of mango cultivar Safeda was subjected to physicochemical analysis, *viz*., total soluble solids, acidity, pH, ascorbic acid, total reducing sugar, total carotenoids, pectin, and phenols. The results obtained on account of this parameter were found as (19.56%), (0.41%), (5.49), (6.91 mg/100 g), (5.84%) as compared to (9.90%), (1.24 mg/100 g), (0.50%) and (41.77 mg/100 g), respectively. Freshly prepared unblended milk yogurt and corn milk yogurt were compared for their physicochemical properties. For corn milk yogurt titratable acidity (TTA), pH, total soluble solids (TSS), fat and protein content were estimated as 0.40%, 5.61, 18.7%, 2.20%, 2.18% while for milk yogurt their values were found as 0.32%, 5.81, 19.18%, 5.67%, 2.80% respectively. Freshly prepared mango blend yogurt samples were also analyzed for physico-chemical characteristics (Table 2). Estimated acidity of MLDY, CLDY, MLCY and CLCY was 0.35%, 0.44%, 0.40% and 0.46%, respectively. The total acidity estimation is helpful as a measure of the tartness of the product. Corn milk yogurt was found to have significantly higher acidity than milk yogurt for both bacterial strains. Alternatively, pH values were lower. This could be attributed to the lower buffering capacity of corn milk. The pH values obtained at zero days for MLDY (5.8), CLDY (5.59), MLCY (5.67) and CLCY (5.54) were comparatively higher than the results reported by (Wang *et al.*, 12). There was no significant difference in total soluble solids. The fibrous nature of ingredients like mango and corn milk led to a comparatively constant TSS content in all the mango blend yogurts. Fat and protein content decreased gradually over storage. Milk yogurt had a higher amount of fat. (Supavititpatana *et al.*, 4)

Table 2. Physico-chemical analysis of fresh mango blended yogurt samples.

Parameter	Treatment				
	MLDY	CLDY	MLCY	CLCY	CD at 5%
Titratable acidity (% lactic acid)	0.91±.002	0.96±.006	0.97±.003	0.99±.007	0.01
pH	4.98±.01	4.89±.01	4.91±.02	4.81±.01	0.02
Total soluble solids (%)	20.57±.06	20.10±.10	21.07±.12	20.50±.01	0.15
Water holding capacity (WHC) (%)	70.52±.67	50.23±.71	60.83±.75	55.67±.64	1.35
Fat (%)	5.51±.07	2.16±.04	5.50±.04	2.15±.05	0.07
Protein (%)	2.84±.05	2.20±.06	2.95±.03	2.34±.04	0.07

observed a higher protein but lower fat and total soluble solids in corn milk yogurt than in cow milk yogurt. Milk yogurt was found to have significantly higher water holding capacity than corn milk-based yogurt due to higher fat content and fibrous network provided by mango fruit incorporation, which would help form a dense gel network.

There was no significant difference in TSS among milk and corn milk yogurt samples (Table 2). Milk yogurt MLDY and MLCY showed substantially higher WHC than corn milk yogurt due to higher fat content and fibrous network provided by mango fruit incorporation, which would help form a dense gel network in milk yogurt. Milk yogurt had more fat and protein than corn (Nasution and Wahyuni, 3). Plant-based or non-dairy milk alternative is the fast-growing segment that has gained universal interest in response to significant trends in food consumption, such as lactose intolerance, vegetarianism, veganism and low-fat content foods (Aydar *et al.*, 5). Physicochemical changes that occurred during the storage of mango blended yogurt samples are presented in Table 3.

There was a significant increase in TTA in all yogurt treatments during the storage (Table 3). Lactic acid is the most important acid found in lactic acid fermentation, which imparts a mildly acidic taste, which could be described as "tart" or "acrid". Comparatively, the TTA of corn milk yogurt samples CLDY (0.96 to 1.33) and CLCY (0.99 to 1.35) was higher than that of milk yogurt sample MLDY (0.91 to 1.26) and MLCY (0.97 to 1.29), which may be attributed to the acidic nature of maize proteins (zein); similar results were obtained by (Jaster *et al.*, 13). Increased acidity in mango blended yogurt may also be attributed to the higher acidity level of mango. After every weekly interval, a significant decrease in pH in different mango blend yogurt samples was observed (Table 3). In MLDY, the changes from zero-day to third week were (4.98 to 4.62), and in CLDY (4.89 to 4.57), which was significantly higher than MLDY. The pH of CLCY (4.54) at the end of three weeks was significantly lower than all other treatments. The addition of mango pulp automatically improved the pH of the yogurt during storage. It was observed that there was a significant decrease in TSS after every weekly interval. In MLCY, TSS (21.07 to 18.45) in three weeks, while in CLCY (20.50 to 18.13). If compared among the samples, MLDY had the lowest TSS at the end of three weeks (Table 3). Corn extrudate and mango pulp supposedly increase the total soluble solids in the corn milk yogurt samples.

In contrast, milk yogurt samples' lack of these ingredients reduces their total soluble solids faster.

Table 3. Physico-chemical changes during storage of mango blended yogurt samples.

Parameter	Treatment	Storage (weeks) 0	1	2	3	Mean
Titratable acidity (%)	MLDY	0.40	0.74	0.97	1.17	0.82
	CLDY	0.35	0.73	0.96	1.11	0.79
	MLCY	0.46	0.78	1.05	1.24	0.88
	CLCY	0.44	0.77	1.00	1.18	0.85
	Mean	0.41	0.75	1	1.17	
	CD at 5%	Treatment (T) = 0.005, Storage (S) = 0.005, T × S = 0.009				
pH	MLDY	5.67	4.84	4.26	3.78	4.64
	CLDY	5.8	4.86	4.3	3.91	4.71
	MLCY	5.54	4.75	4.07	3.62	4.49
	CLCY	5.59	4.76	4.2	3.75	4.58
	Mean	5.66	4.8	4.21	3.76	5.66
	CD at 5%	Treatment (T) = 0.018, Storage (S) = 0.018, T × S = 0.037				
Total soluble solids (%)	MLDY	21.07	21.17	19.23	18.45	19.98
	CLDY	20.57	19.23	16.23	14.83	17.72
	MLCY	20.5	19.07	18.83	18.13	19.13
	CLCY	20.1	19.68	19.65	19.64	19.77
	Mean	20.56	19.79	18.49	17.76	20.56
	CD at 5%	Treatment (T) = 0.093, Storage (S) = 0.093, T × S = 0.186				
Fat (%)	MLDY	5.5	5.49	5.49	5.48	5.49
	CLDY	5.51	5.5	5.49	5.48	5.50
	MLCY	2.15	2.15	2.13	2.12	2.14
	CLCY	2.16	2.15	2.13	2.11	2.14
	Mean	3.83	3.82	3.81	3.80	3.83
	CD at 5%	Treatment (T) = 0.049, Storage (S) = 0.049, T × S = 0.098				
Crude protein (%)	MLDY	2.95	2.73	2.85	2.92	2.86
	CLDY	2.84	2.62	2.79	2.8	2.76
	MLCY	2.34	2.14	2.2	2.31	2.25
	CLCY	2.2	2.03	2.1	2.15	2.12
	Mean	2.58	2.38	2.49	2.55	2.58
	CD at 5%	Treatment (T) = 0.049, Storage (S) = 0.049, T × S = 0.098				
Water holding capacity (%)	MLDY	60.83	53.4	58.34	61.83	58.6
	CLDY	70.52	63.24	68.37	69.45	67.83
	MLCY	55.67	44.52	53.71	54.31	51.93
	CLCY	50.23	42.58	51.24	52.67	49.18
	Mean	59.39	50.84	57.84	59.57	59.39
	CD at 5%	Treatment (T) = 0.37, Storage (S) = 0.37, T × S = 0.741				

Garg *et al.* (14) prepared ketchup from ripe mango and guava fruits, comprising pulp extraction by traditional methods, homogenization, and adding sugar, salt, spices, acetic acid, *etc*. At the same time, the non-enzymatic browning increased from 0.089 to 0.174 and 0.373 to 0.577 after nine months of storage. A slight increase in TSS and acidity was observed.

Fat content was higher in MLDY (5.51 to 5.48) and MLCY (5.50 to 5.48) than in CLDY (2.16 to 2.11) and CLCY (2.15 to 2.12). Incorporating mango fruit pulp helped reduce the fat percentage in mango blended yogurt samples. Among samples, MLCY had the highest protein content at the end of three weeks. Protein content decreased significantly in the first week in all samples but increased afterwards (Table 3). At first, the reduction in protein may be due to the proteolytic activity of probiotic bacteria, which break the complex structure of proteins into simple peptides, thus decreasing protein levels. However, after the second week, the protein levels may be increased due to the destruction of microbial protein by protease enzymes (Najafi *et al.*, 15). The WHC, as an indirect measure of network homogeneity, showed a decrease in the first week but an increase after that. There was a significant change in WHC in different mango blend yogurt after every week (Table 3). MLDY's changes from zero-day to third week were (70.52 to 69.45), and CLDY (50.23 to 52.67) were significantly lower than MLDY. In MLCY, in three weeks, WHC changed (60.83 to 61.83), while in CLCY (55.67 to 54.31). WHC of CLCY, at the end of three weeks, was significantly lower than that of all other treatments. The results during storage agree with (Najafi *et al.*, 15), where the water-holding capacity of yogurt was reduced initially but increased after that.

The organoleptic quality of yogurt was recorded at weekly intervals during storage. Changes in taste (Fig. 2a), and aroma and flavor scores (Fig. 2b) of mango blend yogurt samples are presented below:

In the present study, mango blend yogurt was prepared, resulting in good taste (Fig. 2a), body and texture (Fig. 2b) of all the samples, and improved WHC during storage for up to 21 days. The pectin and fructose of mango fruits improve the consistency and viscosity of yogurt by getting mixed with it, enhancing the aroma and flavour. Arioui *et al.* (16) observed that pectin incorporation at a rate of 0.6% significantly improved the rheological quality of the yogurt, particularly viscosity, adhesiveness and cohesiveness. Thakur *et al.* (2) recorded the stability of a mango drink enriched with micro-encapsulated pomegranate peel extract. A mango drink was prepared with or without adding microencapsulated phenolic extract powder from wild pomegranate peel. After incorporating microencapsulated pomegranate peel phenolic extract powder, a comparative evaluation of mango drinks revealed a significant increase in total phenols and flavonoids with various antioxidant properties. Antioxidant-enriched mango drinks can safely be stored for six months without much quality changes under both storage conditions. Combining the intake of yogurt and fruit could provide probiotics, prebiotics, high-quality protein, essential fatty acids, polyphenols, vitamins and minerals that can synergistically affect health (Nasution and Wahyuni, 3). Mango provides sweetness and influences yogurt's textural and sensory characteristics (Kumar and Mishra, 17).

All the yogurt samples retained a good appearance till three weeks of storage, and the colour score of MLCY was significantly higher than other treatments. The aroma and flavour scores of MLCY, CLCY, MLDY and CLDY were 7.5, 7.45, 7.36 and 7.18, respectively. All the mango blend yogurt samples were acceptable after three weeks of storage. However, the increased acidity and off-flavours were evident due to metabolically active microbial cultures. The overall acceptability scores of CLCY (7.65) was higher than those of MLCY (7.6), CLDY (7.45), and MLDY (7.28) at zero-day.

Mango blend yogurt variants after 14 days (Fig. 3a) and 21 days of storage (Fig. 3a) were organoleptically

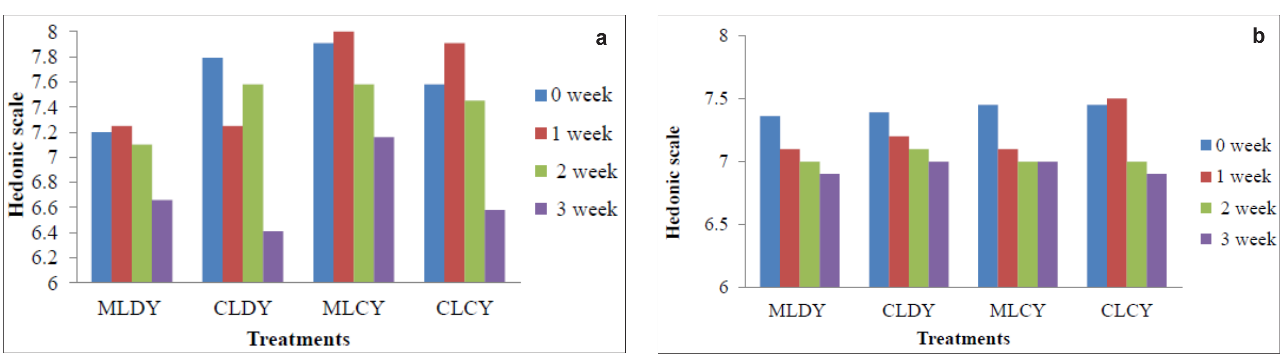

Fig. 2. (a) Changes in taste and (b) aroma & flavor scores of mango blended yogurt samples.

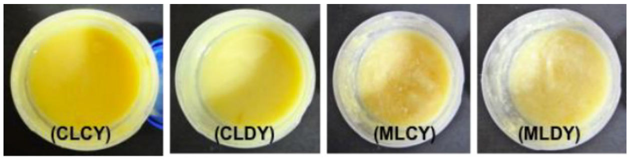

Fig. 3a. Mango blend yogurt variants after 14 days of storage

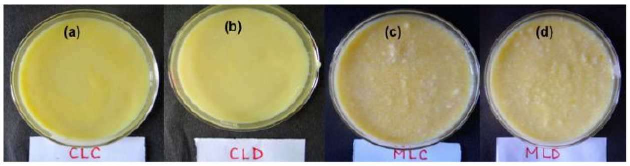

Fig. 3b. Mango blend yogurt variants after 21 days of storage

Fig. 3. Mango blend yogurt variants after (a) 14 days of storage and (b) 21 days of storage.

acceptable. Biswas *et al.*, (18) confirmed that the addition of mango juice with cow's skim milk dahi or buffalo skim milk dahi were both better in terms of organoleptic and chemical qualities and, thus, more acceptable than plain skim milk dahi. Phong *et al.* (1) found that the blend of mango cv. Langra and Dashehari, having carrot pulp in the proportions 40:40:20, were adjudged best for the enrichment of β-carotene and good colour, without change in mango flavour and taste in the blend after storage. Tandon *et al.* (19) observed improved quality of beverages prepared from Rumani mango blended with Dashehari and Mallika. The addition of mango pulp improved the colour with a significant increase in the yellowness index and total carotenoids content. A significant increase in the content of total soluble solids (TSS) and total sugars was also observed by pulp blending. Mango blended yogurt samples with *L. casei* had the highest 8 log10 CFU/ml probiotic count at the end of three weeks of storage. Hence, they fulfilled the requirements of probiotic food. Enhanced proliferation of *S. thermophilus* and *L. bulgaricus* was observed during fermentation when pectin was added to yogurt. Additionally, when blended in yogurt, the phenolic compounds rich in mango fruits might act as a substrate for probiotics, increasing their survival and functionality (Biswas *et al.*, 18). Similarly, synbiotic yogurt was developed by Nasution and Wahyuni (3) using *L. acidophilus* and *B. bifidum* as probiotics and sweet corn, honey and full-cream milk as prebiotics.

Mango cv. Safeda blended corn milk yogurt is a novel probiotic product. Mango blended corn milk and milk yogurt prepared with *L. casei* were better than *L. delbrueckii*. Among all the mango-blend yogurt variants, CLCY was found to have the highest overall acceptability at the end of the storage period. Shelf stability of three weeks confers its commercial viability as a new product in the market. Corn milk yogurt could be blended with other fruits to add variety in taste and nutrition. Future research is focused on exploring the methods to further enhance the stability and shelf-life of probiotic corn milk yogurt under varying storage conditions. Diverse probiotic strains could be evaluated to determine their compatibility with corn milk and their impact on health benefits, texture, and taste. Large-scale consumer preferences and market studies can be conducted to fine-tune product formulations and assess the market viability of producing corn-based probiotics compared to other plant-based alternatives, ensuring eco-friendly practices.

AUTHORS' CONTRIBUTION

Execution of lab experiments, Data collection and data analysis (MR); Conceptualization of research, Contribution of experimental material and supervision of research (AK).

DECLARATION

The authors declare that they have no conflict of interest. Publication has been approved by all co-authors The work described has not been published before and not under consideration for publication anywhere else.

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