
Development of pudding products from young rice milk supplemented with whey protein and inulin

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Abstract This study is developed a healthy pudding by integrating plant-based milks with a natural non-nutritive sweetener and functional ingredients to enhance both nutritional value and consumer acceptability. Young rice milk and cereal coconut milk blends (100:0–0:100 w/w) were first optimized, with a 50:50 ratio achieving the highest sensory acceptance. Monk fruit (*Siraitia grosvenorii*) extract–sucrose ratios (100:0–0:100 w/w) were subsequently evaluated, and 25:75 was most preferred. Six whey protein–inulin formulations, namely W8I2, W8I4, W10I2, W10I4, W12I2, and W12I4, were assessed, where W and I represent whey protein (%) and inulin (%) concentrations, respectively. An increase in whey protein concentration was associated with greater hardness and gumminess, while no significant differences were observed in sensory scores ($p > 0.05$), except for the W12I4 formulation. The W12I2 formulation provided 61.04% moisture, 0.66% ash, 12.16% protein, 6.40% fat, and 19.10% total carbohydrates. During refrigerated storage (4 ± 2 °C), hardness and gumminess increased, while microbial quality met community product standards. The novelty of this work lies in the combined use of young rice milk, cereal coconut milk, and monk fruit extract to produce a plant-based, nutritionally enhanced pudding with reduced sugar content, offering a promising alternative for health-conscious consumers and the functional dessert market.

Keywords: Rice milk, Monk fruit, Pudding, Inulin, Whey protein

Introduction

Recent shifts in dietary preferences, characterized by an increasing demand for high-protein foods and a departure from traditional dietary patterns, have intensified interest in health-oriented products across all age groups (Vaccaro *et al.*, 2024). Since diet has a direct impact on consumer health, food intake alone may be inadequate to address specific nutritional demands. To overcome this gap, the incorporation of additional nutrients into food products has been widely applied. For instance, fortification with prebiotics, probiotics, or dietary fiber

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offers alternative options to improve the nutritional value of foods and better support consumer well-being.

Pudding is a versatile food product that can be consumed as both a savory and sweet dish. Traditionally, its main ingredients include fresh milk, whipped cream, sugar, and gelatin (Pasukamonset *et al.*, 2018). However, when consumed as a dessert, pudding typically contains high sugar content and provides limited nutritional value. High-sugar desserts deliver excess energy, promoting weight gain and elevating type 2 diabetes risk independent of adiposity (Te Morenga *et al.*, 2013; Imamura *et al.*, 2015). To enhance its health benefits, efforts have been made to reformulate pudding with more nutritious ingredients. For instance, milky stage rice milk has been shown to contain bioactive short-chain peptides with good digestibility, making it a promising substitute for enhancing the nutritional value of pudding (Ngamsuk *et al.*, 2020). In addition, commercially available coconut-milk analogues, typically formulated with plant protein isolates, vegetable oils, and stabilizers, are cholesterol-free and contain a higher proportion of unsaturated fatty acids than conventional coconut milk that can be incorporated as a lower-saturated-fat alternative in pudding reformulation (Xie *et al.*, 2023). To mitigate health concerns associated with sugar, monk fruit (*Siraitia grosvenorii*) extract may be used as a natural, non-nutritive sweetener in desserts (Gong *et al.*, 2019). In addition, whey protein and inulin are commonly incorporated to increase protein content and confer prebiotic effects, improving the product's overall nutritional profile. Such modifications not only increase the nutritional value of pudding but also provide a healthier option for consumers seeking functional and health-conscious foods.

This research aimed to develop a pudding product based on young rice milk supplemented with whey protein and inulin. The optimal proportion of young rice milk to cereal coconut milk, the sweetener ratio of monk fruit extract to sucrose, and the combination of whey protein and inulin for textural enhancement were determined. Product quality and stability during refrigerated storage were subsequently evaluated.

Materials and methods

Young (milky-stage) rice milk (Diamond Fresh Global (Thailand) Co., Ltd., Thailand); cereal coconut milk (Tastifit, 4Care Co., Ltd.); whey protein powder (Fresenius Kabi (Thailand) Co., Ltd.); inulin powder (Nise, 4Care Co., Ltd.); refined white sugar (sucrose; Lin, Intelligence Business (Thailand) Co., Ltd.); gelatin powder (McGarrett, JR F&B Co., Ltd.); monk fruit (*Siraitia grosvenorii*) extract (Wellness); and pandan leaf powder (BK, BK Beverages & Bakery Co., Ltd.) were used in this study.

Preparation of young rice milk

The young rice grains were washed thoroughly 4–5 times and then blotted dry. The grains were blended with water, and the mixture was filtered through a muslin cloth to remove the rice residues. The obtained filtrate was collected and used as young rice milk (YRM) for prepare pudding samples.

Pudding preparation

The preparation of pudding was modified from Ruangthamsing *et al.* (2016). First, YRM, cereal coconut milk (CCM), and sucrose were mixed until dissolved and heated to 40–45 °C. A portion of the YRM was used to dissolve gelatin at a ratio of 1:3 (w/w), after which the gelatin solution was added to the mixture. Heating was continued until the temperature reached 60 °C, then pandan powder was incorporated and stirred until fully dissolved. The mixture was then refrigerated for 8–12 h prior to further analysis.

The optimum ratio between YRM and CCM in pudding was investigated by varying 5 ratios of YRM to CCM (100:0, 75:25, 50:50, 25:75, and 0:100, w/w). Subsequently, the optimum ratio between Monk fruit extract and sucrose was studied by varying 5 ratios of Monk fruit extract to sucrose (100:0, 75:25, 50:50, 25:75, and 0:100, w/w). Finally, the optimum ratio between whey protein and inulin was investigated by varying six levels (8:2, 8:4, 10:2, 10:4, 12:2, and 12:4, w/w) to improve the texture properties and nutritional profile of pudding. These formulations, denoted as W8I2, W8I4, W10I2, W10I4, W12I2, and W12I4, where W and I represent whey protein (%) and inulin (%) concentrations, respectively, were evaluated. The experimental design was a completely randomized design (CRD). The results were reported as the mean value with standard deviation. Statistics were analyzed using SPSS for Windows and Duncan's multiple range test (DMRT) was used for comparing the differences among mean values at the 95% confidence level ($p \leq 0.05$).

Textural properties

The texture of pudding samples was performed by Texture Profile Analysis as described by Abdo Qasem *et al.* (2017) with modification, using a Texture Analyzer TA-XTplusC (Stable Micro Systems, UK), equipped with a P/50 cylindrical probe. Samples were prepared as cylinders (35 mm diameter × 10 mm height) and compressed twice to 50% of their original height at room temperature. The test speed was set at 1 mm/s. The parameters evaluated included hardness, springiness, cohesiveness, and gumminess.

Sensory evaluation

The pudding samples were subjected to sensory evaluation using the 9-point Hedonic Scale method with 40 untrained panelists. The rate of the quality attributes included appearance, color, flavor, taste, texture, and overall acceptability of each sample using a 9-point hedonic scale from 1 (dislike extremely) to 9 (like extremely). Each sample was coded with a randomized three-digit number to avoid bias, and water was provided to panelists for palate cleansing between evaluations.

Nutritional composition

The nutritional composition of the optimal pudding formulation was determined for moisture, fat, ash, and protein. Total carbohydrate content was calculated by difference (AOAC, 1999).

Microbial analysis

The optimized pudding formulation was analyzed for microbiological quality following the AOAC (2000) method. Total plate counts (TPC) were determined in samples stored at $4 \pm 2^\circ\text{C}$ for 1, 3, 5, and 7 days. The colonies were counted and expressed as a log of forming units per gram of sample (log CFU/g).

Results

The texture properties of puddings formulated with different ratios of young rice milk and cereal coconut milk are presented in Table 1. As the proportion of young rice milk was decreased and cereal coconut milk was increased to a 50:50 (w/w) ratio, hardness, springiness, cohesiveness, and gumminess were observed to increase. However, when the young rice milk ratio was reduced to 25%, hardness and gumminess decreased, while springiness and cohesiveness remain relatively consistent.

The sensory evaluation of puddings prepared with various ratios of monk fruit extract and sucrose is shown in Table 2. The formulation containing a 50:50 ratio of young rice milk to cereal coconut milk received the highest overall acceptance score of 7.45, corresponding to a preference level between “like moderately” and “like very much.” Accordingly, this formulation was selected for further study.

Table 1. Texture properties of pudding from various ratios of young rice milk and cereal coconut milk

YRM:CCM ¹ (%w/w)	Mean ± standard deviation			
	Hardness (gr)	Springiness	Cohesiveness	Gumminess (gr)
100:0	380.36 ^d ± 24.95	0.96 ^{ab} ± 0.02	0.87 ^d ± 0.03	330.29 ^e ± 20.58
75:25	439.73 ^c ± 26.46	0.96 ^{ab} ± 0.01	0.89 ^b ± 0.02	393.25 ^c ± 25.77
50:50	616.81 ^a ± 14.03	1.03 ^a ± 0.01	0.94 ^{ab} ± 0.01	560.71 ^a ± 16.18
25:75	396.33 ^d ± 11.77	0.95 ^b ± 0.01	0.91 ^a ± 0.01	361.17 ^d ± 10.34
0:100	445.92 ^c ± 20.27	0.96 ^{ab} ± 0.02	0.91 ^{ab} ± 0.01	405.47 ^{bc} ± 20.79
Control	472.89 ^b ± 23.15	0.93 ^c ± 0.01	0.88 ^{cd} ± 0.01	416.94 ^b ± 20.05

^{a-c} Mean values in a column with different letters are significantly different ($p \leq .05$)

¹ YRM = Young rice milk, CCM = cereal coconut milk

Table 2. Sensory evaluation of pudding from various ratios of young rice milk and cereal coconut milk

YRM: CCM ¹ (%w/w)	Mean ± standard deviation					
	Appearance	Color	Flavor	Taste	Texture	Overall accepted
100:0	5.40 ^c ± 2.12	4.68 ^c ± 2.04	6.55 ^b ± 1.58	6.30 ^c ± 1.86	6.43 ^{ab} ± 2.01	6.28 ^{bc} ± 1.69
75:25	6.23 ^b ± 1.70	5.70 ^b ± 1.77	6.68 ^b ± 1.49	6.40 ^{bc} ± 1.75	6.53 ^{ab} ± 1.62	6.60 ^b ± 1.48
50:50	7.48 ^a ± 1.09	7.38 ^a ± 1.07	7.40 ^a ± 1.06	7.33 ^a ± 1.25	7.03 ^a ± 1.61	7.45 ^a ± 1.22
25:75	7.90 ^a ± 1.28	7.50 ^a ± 1.08	7.10 ^{ab} ± 1.60	6.98 ^{ab} ± 1.42	7.10 ^a ± 1.28	7.38 ^a ± 1.38
0:100	7.63 ^a ± 1.55	8.05 ^a ± 1.56	5.68 ^c ± 1.99	5.75 ^c ± 2.12	6.00 ^b ± 2.17	5.70 ^c ± 2.07
Control	8.03 ^a ± 1.27	8.23 ^a ± 1.05	7.73 ^a ± 1.34	7.45 ^a ± 1.68	7.03 ^a ± 2.01	7.43 ^a ± 1.77

^{a,b,c} Mean values in a column with different letters are significantly different ($p \leq .05$)

¹ YRM = Young rice milk, CCM = cereal coconut milk

The texture properties of puddings prepared with different ratios of monk fruit extract and sucrose are shown in Table 3. As the proportion of monk fruit extract decreased, significant decreases ($p \leq 0.05$) in hardness and gumminess were observed, whereas springiness increased slightly and remained relatively constant. Cohesiveness did not differ significantly ($p > 0.05$) among the treatments. Additionally, hardness increased when monk fruit extract was completely absent (0%).

The sensory evaluation of pudding prepared with different ratios of Monk fruit extract and sucrose is shown in Table 4. The control sample received the highest overall acceptability score; however, since it contained no monk fruit extract, it was not selected in line with the research objective. Instead, the formulation with monk fruit extract and sucrose at a ratio of 25:75, which scored the second-highest overall acceptability of 7.55 (like moderately to like very much) and did not differ significantly from the control ($p > 0.05$), was chosen for further investigation.

Table 3. Texture properties of pudding from various ratios of Monk fruit extract and sucrose

Monk fruit extract: sucrose (%w/w)	Mean \pm standard deviation			
	Hardness (gr)	Springiness	Cohesiveness ^{ns}	Gumminess (gr)
100:0	519.55 ^a \pm 24.20	0.96 ^b \pm 0.01	0.88 \pm 0.01	450.80 ^a \pm 25.47
75:25	454.28 ^b \pm 33.62	0.96 ^b \pm 0.00	0.88 \pm 0.01	400.66 ^b \pm 15.29
50:50	452.47 ^b \pm 12.16	0.97 ^a \pm 0.01	0.88 \pm 0.01	370.86 ^c \pm 20.25
25:75	290.11 ^d \pm 8.49	0.96 ^b \pm 0.02	0.87 \pm 0.02	287.99 ^d \pm 24.42
0:100	335.58 ^c \pm 34.26	0.97 ^a \pm 0.00	0.88 \pm 0.00	261.67 ^e \pm 9.33

^{a-c} Mean values in a column with different letters are significantly different ($p \leq .05$)

^{ns} Mean values are not significantly different ($p > .05$)

Table 4. Sensory evaluation of pudding from various ratios of Monk fruit extract and sucrose

Monk fruit extract: sucrose (%w/w)	Mean \pm standard deviation					
	Appearance	Color	Flavor	Taste ^{ns}	Texture	Overall accepted
100:0	7.35 ^b \pm 1.37	6.33 ^d \pm 1.65	6.90 ^b \pm 1.34	6.80 \pm 1.49	7.23 ^b \pm 1.42	6.85 ^c \pm 1.42
75:25	7.35 ^b \pm 1.33	6.43 ^d \pm 1.59	7.05 ^b \pm 1.13	6.83 \pm 1.48	7.48 ^{ab} \pm 1.18	7.05 ^{bc} \pm 1.20
50:50	7.50 ^b \pm 1.26	7.03 ^c \pm 1.27	7.33 ^{ab} \pm 1.20	7.23 \pm 1.07	7.50 ^{ab} \pm 1.28	7.23 ^{bc} \pm 0.95
25:75	7.93 ^{ab} \pm 1.25	7.63 ^b \pm 1.15	7.70 ^a \pm 1.07	7.23 \pm 1.08	7.73 ^{ab} \pm 1.23	7.55 ^{ab} \pm 1.11
0:100	8.10 ^a \pm 1.19	8.28 ^a \pm 0.82	7.83 ^a \pm 0.84	7.43 \pm 1.28	7.90 ^a \pm 1.26	7.85 ^a \pm 0.98

^{a-d} Mean values in a column with different letters are significantly different ($p \leq .05$)

^{ns} Mean values are not significantly different ($p > .05$)

The texture properties of pudding prepared with different ratios of whey protein and inulin are shown in Table 5. An increase in the proportion of whey protein and inulin was associated with significant increases ($p \leq 0.05$) in hardness and gumminess, while springiness and cohesiveness showed a rising trend and then remained relatively constant.

Table 5. Texture properties of pudding from various ratios of whey protein and inulin

Formulation code	Mean \pm standard deviation			
	Hardness (gr)	Springiness	Cohesiveness	Gumminess (gr)
W8I2	269.50 ^d \pm 28.29	0.97 ^c \pm 0.02	0.88 ^b \pm 0.03	265.62 ^d \pm 20.75
W8I4	499.90 ^c \pm 45.85	0.97 ^{bc} \pm 0.01	0.87 ^b \pm 0.01	436.55 ^c \pm 40.45
W10I2	509.58 ^c \pm 19.11	0.99 ^a \pm 0.01	0.90 ^a \pm 0.01	458.69 ^c \pm 17.45
W10I4	557.18 ^b \pm 13.25	0.98 ^{abc} \pm 0.01	0.90 ^a \pm 0.01	493.04 ^b \pm 23.98
W12I2	564.78 ^b \pm 15.77	0.98 ^{ab} \pm 0.00	0.90 ^a \pm 0.01	506.40 ^b \pm 21.93
W12I4	636.03 ^a \pm 19.38	0.97 ^c \pm 0.02	0.88 ^b \pm 0.01	545.32 ^a \pm 24.63

^{a-d} Mean values in a column with different letters are significantly different ($p \leq .05$)

Formulations are coded as W8I2, W8I4, W10I2, W10I4, W12I2, and W12I4, where W and I denote whey protein (%) and inulin (%) concentrations, respectively.

The sensory evaluation of pudding prepared with different ratios of whey protein and inulin is shown in Table 6. No significant differences ($p > 0.05$) were observed in the overall acceptability scores among the formulations, with the exception of W12I4, which received an overall acceptability score of 6.95 (like slightly to like moderately). Therefore, the formulation W12I2 was selected as the optimum pudding formulation for further nutritional evaluation.

Table 6. Sensory evaluation of pudding from various ratios of whey protein and inulin

Formulation code	Mean \pm standard deviation					
	Appearance	Color ^{ns}	Flavor ^{ns}	Taste	Texture	Overall accepted
W8I2	7.95 ^a \pm 0.88	7.75 \pm 1.03	7.85 \pm 1.25	7.25 ^a \pm 1.56	7.60 ^a \pm 1.45	7.64 ^a \pm 1.17
W8I4	7.78 ^a \pm 1.30	7.68 \pm 0.86	7.25 \pm 1.35	7.35 ^a \pm 1.58	7.38 ^{ab} \pm 1.60	7.55 ^{ab} \pm 1.30
W10I2	7.58 ^a \pm 1.20	7.55 \pm 1.04	7.33 \pm 1.27	7.25 ^a \pm 1.48	7.28 ^{abc} \pm 1.40	7.50 ^{ab} \pm 1.20
W10I4	7.50 ^a \pm 1.14	7.70 \pm 1.10	7.40 \pm 1.15	7.28 ^a \pm 1.38	7.35 ^{ab} \pm 1.23	7.48 ^{ab} \pm 1.04
W12I2	7.73 ^a \pm 1.20	7.38 \pm 1.15	7.35 \pm 1.08	7.15 ^a \pm 1.08	7.05 ^{abc} \pm 1.41	7.10 ^{abc} \pm 1.04
W12I4	6.90 ^b \pm 1.17	7.30 \pm 1.11	7.23 \pm 1.14	6.90 ^b \pm 1.37	6.65 ^{bc} \pm 1.55	6.95 ^{bc} \pm 1.30

^{a-c} Mean values in a column with different letters are significantly different ($p \leq .05$)

^{ns} Mean values are not significantly different ($p > .05$)

Formulations are coded as W8I2, W8I4, W10I2, W10I4, W12I2, and W12I4, where W and I denote whey protein (%) and inulin (%) concentrations, respectively.

The nutritional composition of the optimized pudding formulation prepared from young rice milk supplemented with whey protein and inulin is presented in Table 7. The composition of 100 g pudding consisted of 61.04 g moisture, 6.40 g fat, 0.66 g ash, 12.16 g protein, 12.24 g fiber and 7.50 g total carbohydrate.

Table 7. Nutritional value of pudding from young rice milk supplemented with whey protein and inulin

Composition	Mean \pm standard deviation
	gram per 100 gram
Moisture	61.05 \pm 0.02
Fat	6.41 \pm 0.10
Ash	0.66 \pm 0.02
Protein (N*6.25)	12.17 \pm 0.12
Total Carbohydrate	19.71 \pm 0.21

Texture properties and total plate counts (TPC) of pudding from young rice milk supplemented with whey protein and inulin during refrigerated storage are shown in Table 8. Hardness and gumminess increased with longer storage duration, while springiness showed a slight increase and remained relatively

constant. Cohesiveness decreased over time. No microbial growth was detected throughout the storage period.

Table 8. Texture properties and total plate counts (TPC) of pudding from young rice milk supplemented with whey protein and inulin during refrigerated storage for 7 days

Storage time (days)	Mean \pm standard deviation				
	Hardness (gr)	Springiness	Cohesiveness	Gumminess (gr)	TPC (CFU/g)
1	246.13 ^c \pm 21.65	0.97 ^b \pm 0.01	0.90 ^a \pm 0.02	221.48 ^c \pm 17.41	< 100
3	256.93 ^c \pm 13.98	0.97 ^b \pm 0.01	0.89 ^a \pm 0.03	234.11 ^c \pm 12.66	< 100
5	410.90 ^b \pm 30.85	0.99 ^a \pm 0.01	0.85 ^b \pm 0.02	330.56 ^b \pm 41.99	< 100
7	437.86 ^a \pm 20.72	0.98 ^a \pm 0.00	0.86 ^b \pm 0.02	378.50 ^a \pm 14.13	< 100

^{a,b,c} Mean values in a column with different letters are significantly different ($p \leq .05$)

Discussion

This study investigated the effects of different ingredient ratios and functional substitutions on the textural and sensory characteristics of pudding. The factors examined were the ratio of YRM to CCM, the substitution of sucrose with monk fruit extract, and the incorporation of whey protein and inulin. Each factor exerted distinct effects on the gel matrix and overall product acceptability.

The optimum ratio between YRM and CCM in pudding was investigated by varying five ratios of 100:0, 75:25, 50:50, 25:75, and 0:100 (w/w) to replace fresh milk and whip cream in original pudding formulation. YRM was selected as a substitute for fresh milk due to its enhanced nutritional properties (Pantoa *et al.*, 2020) and lower allergenicity. CCM was used in place of whipped cream as a plant-based fat source that can mimic creaminess while reducing saturated fat and providing a dairy-free alternative (Suzauddula *et al.*, 2020). The results revealed that when the proportion of YRM decreased and CCM increased, the puddings became firmer, as indicated by increases in hardness, springiness, cohesiveness, and gumminess. This effect is likely attributed to the higher lipid content of CCM, which contains approximately 35.2% fat and 3.8% protein (Chen *et al.*, 2024b). The increased lipid molecules may act as an active filler within the protein network through hydrophobic interactions, thereby enhancing gel strength (Zhang *et al.*, 2023). This finding is consistent with Tang *et al.* (2025), who reported that oil addition enhanced the gel strength of soy protein isolate emulsion gels. Similarly, Zhang *et al.* (2020) observed that increasing oil content improved the firmness of egg–soy protein emulsion gels. Whereas at higher fat levels, when the proportion of CCM reached 75–100%, the puddings became softer, as reflected by decreases in hardness and gumminess. A similar

result was reported by Absalimova *et al.* (2025), who observed that when coconut oil exceeded 60% of the total lipid content in gel systems, the protein matrix was disrupted, resulting in decreased gel strength. This softening effect is likely due to the excess lipid phase no longer being fully integrated into the protein network, instead acting as discontinuities that disrupt the structural equilibrium and weaken gel integrity (Absalimova *et al.*, 2025; Aruchunan *et al.*, 2025). Moreover, the lubricating effect of fat droplets may facilitate slippage or reduce friction between protein chains, thereby weakening protein–protein interactions and further decreasing gel strength (Giles *et al.*, 2025; Benković *et al.*, 2023). In terms of sensory evaluation, the formulation containing a 50:50 ratio of YRM to CCM received the highest overall acceptance score. Consequently, this formulation was selected for further investigation of the optimum ratios between monk fruit extract and sucrose, with the objective of minimizing sucrose content while preserving desirable texture properties and overall consumer acceptability.

The optimum ratio between monk fruit and sucrose extract in pudding was investigated by varying 5 ratios of 100:0, 75:25, 50:50, 25:75, and 0:100 (w/w). The results showed that higher levels of monk fruit extract produced harder puddings, with increases in hardness and gumminess, while springiness tended to slightly decrease and cohesiveness remained stable. This trend is associated with the composition of commercial monk fruit sweeteners, in which the sweetness is provided by mogrosides, which are a group of triterpenoid glycosides (Chen *et al.*, 2024a), but erythritol is typically incorporated as a bulking agent (Massoud and Hashem, 2023). Unlike sucrose, which contains multiple hydroxyl groups that enable strong hydrogen bonding and water retention, erythritol has fewer hydroxyl groups and a lower molecular weight. As a result, its water-binding capacity is limited, which is consistent with the findings that sugar alcohols reduce water-binding and gelation compared with sucrose (Ding and Yang, 2021). The reduced association of erythritol with water decreases the extent of tightly bound water surrounding protein chains, thereby allowing closer polymer–polymer proximity and promoting the formation of a denser gel matrix. Furthermore, erythritol crystallizes more readily, thereby reducing its hygroscopicity and water absorption (Gao *et al.*, 2023). These findings are consistent with previous reports indicating that sugar alcohols may impact water structure and promote a more ordered confirmation compared with sucrose (Baydin *et al.*, 2023). In addition, Allan and Mauer (2022) reported that gels made with sugar alcohols showed faster and more pronounced retrogradation than those made with sugars. This characteristic alters water distribution and gel structures, ultimately leading to firmer textures than those observed in sucrose-based systems). In terms of sensory evaluation, the formulation containing monk fruit extract and sucrose at a ratio of 25:75 achieved the second-highest overall

acceptability, following the control sample, which contained no monk fruit extract. Since the aim was to partially replace sucrose with monk fruit extract to reduce sugar content, a major risk factor for obesity and diabetes etc. (Gillespie *et al.*, 2023), while retaining desirable sensory properties, this formulation was considered the most suitable compromise. Consequently, it was selected for subsequent investigation of whey protein and inulin addition for textural and nutritional enhancement.

The six formulations, denoted as W8I2, W8I4, W10I2, W10I4, W12I2, and W12I4, where W and I represent whey protein (%) and inulin (%) concentrations, respectively, were evaluated. The results showed that the addition of whey protein and inulin enhanced the pudding structure, as indicated by increases in hardness and gumminess. Whey protein played a supplementary role in reinforcing the protein network. By increasing the number of linkages between particles, primarily through hydrophobic interactions and disulfide bonding, it enhanced network density (Supavititpatana *et al.*, 2009; Li *et al.*, 2022). Consistently, previous studies have shown that the incorporation of whey protein increased gel hardness, both in yogurt (Antunes *et al.*, 2004; Supavititpatana *et al.*, 2009) and in dairy desserts (Kusio *et al.*, 2020). In a similar manner, inulin, acting as a soluble dietary fiber, increased viscosity and stabilized the gel matrix. The entrapment of water by hydroxyl groups of inulin enables it to form stable gels with high water-holding capacity, while also functioning as a filler within the protein network (Żbikowska *et al.*, 2020; Arab *et al.*, 2023). Similarly, Kristanti and Hermiani (2019) reported inulin-enriched pudding increase gel strength synergistic interactions between whey protein and inulin improved pudding texture, with whey protein contributing elasticity and inulin reinforcing the network. In terms of sensory evaluation, the formulation W12I2 did not negatively affect overall acceptability scores. Therefore, this formulation was selected for the optimum pudding formulation.

The W12I2 formulation, which contained $12.17 \pm 0.12\%$ protein, demonstrated a comparatively high protein content relative to similar products reported previously, such as puddings prepared with cow's milk (3.82% protein) and white bean milk (6.01% protein), both of which contained markedly lower levels (Pasukamonset *et al.*, 2018). Moreover, the elevated protein content may confer additional functional benefits, positioning this formulation as a more nutritious alternative to conventional puddings.

During refrigerated storage, progressive changes in texture were observed. Hardness and gumminess increased over time, while springiness initially rose and then remained relatively stable, and cohesiveness gradually declined, which is likely due to syneresis driven by gel network rearrangement and the progressive strengthening of particle–particle junctions through protein

aggregation within the pudding matrix, ultimately leading to a denser and more rigid gel structure (Arab *et al.*, 2023). Syneresis also involves the expulsion of liquid from the gel, since osmotic pressure promotes swelling and stretching of the polymeric network. This stretching reduces entropy by limiting the number of available conformations, and the polymeric chains then generate an elastic recoil to shrink the gel back to its former state, thereby exerting internal pressure on the entrapped liquid. (Mizrahi, 2010). This finding was in accordance with Fan *et al.* (2019), who reported that the firmness of milk pudding increased significantly ($p < 0.05$) from 3 weeks onwards at 4 ± 1 °C. In addition, inulin supplementation was also found to affect syneresis. According to Kristanti and Herminiati (2019), puddings containing 1.6% (w/w) inulin showed higher syneresis values than those with 0.8% (w/w) inulin after storage at 5 °C for approximately 12 hours.

Microbiological evaluation during storage revealed no detectable microorganisms throughout the entire period, indicating that the product complied with safety requirements and was comparable to other gel-based products, such as jelly manufactured under the Community Product Standard (CPS 519/2004). These results demonstrate the microbiological stability of the pudding and confirm its suitability for safe consumption during the tested storage period.

In summary, the optimum formulation for reduced-sugar, plant-based pudding was a 50:50 blend of young rice milk and cereal coconut milk, combined with a 25:75 ratio of monk fruit extract to sucrose and supplemented with 12% whey protein and 2% inulin. This formulation provided enhanced protein and fiber content, acceptable sensory quality, and stability during refrigerated storage, highlighting its potential as a functional, health-oriented dessert product.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

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