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Colorimetric and Sensory Properties of for Tube Feeding Formulated by Gelatin and Maltodextrin

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ABSTRACT: When nutritional intervention is deemed necessary, it is critical to identify the most appropriate nutrition support technique to ensure its efficacy. Tube feeding, also known as Enteral nutrition is a type of delivery system for patients who are unable to eat food orally. As a novel method to nutritional management, a gelatin-maltodextrin water-in-water emulsion for semi-solid enteral nutrition formulation was used. The color characteristics, turbidity, and sensory evaluation of nineteen experimental formulations were studied after 30 days of storage at 5°C using the I-optimal combination design approach. The color attributes were evaluated after jellifying at 5°C and forming dispersion subsequent to melting at 37°C. The samples with gelatin-to-maltodextrin ratio of (4:4) provided the lowest lightness values in gel (70.74) and dispersion (73.78) forms. The green color values for dispersions are slightly higher (-1.77 - (-2.47)) than for gels (-1.1 - (-2.42)). The gelatin to maltodextrin ratio of 7:1 results in increased yellowness in both the gel (14.07) and dispersion (14) forms. Furthermore, increasing the proportion of maltodextrin to gelatin resulted in a loss in luminosity, a decrease in yellow color, and a tendency towards greenish hues. During the 30-day storage period, there was a distinct increase in turbidity levels. The sensory evaluation results, particularly in the categories of odor, flavor, color, and overall acceptability, revealed that the product was well acceptable. On the tenth day, the ideal formula was determined with a ratio of gelatin-to-maltodextrin of 4.02:3.97% w/w.

Keywords: Colorimetric Properties, Gelatin, Maltodextrin, Sensory Evaluation, Tube Feeding.

Introduction

Nutritional support (NS) in the context of medicine has been a hot topic in recent years. Oral or intravenous administration of specially prepared nutrients to sustain or improve a patient's nutritional status is what's known as "nutritional support treatment" (Lesser & Lesser, 2021; Ong *et al.*, 2021). Enteral nutrition (EN) or tube-feeding formulas (ETF), can be given orally as a dietary supplement to regular meals, or intravenously through a nasogastric, jejunostomy, nasojejunal, or nasoduodenal tube as the patient's primary source of nutrition (Boullata *et al.*, 2009). Polymeric, semi-elementary, elementary, food-based, immune-modulating, disease-specific, and so on are only some of the many categories that can be used to classify EN formulations (Limketkai *et al.*,

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2019). Since most enteral nutrients are administered as liquids, patients may have gastrointestinal distress and the tube may leak. Problems with ETF have been reduced with the help of semi-solidified enteral nutrition(Kanie *et al*., 2004; Nagai *et al*., 2022). Percutaneous endoscopic gastrostomy is used to give semi-solid EN in rehabilitation, long-term care, and home settings due to its high viscosity, which helps reduce diarrhea and aspiration pneumonia (Okabe *et al*., 2022). Gelatin is a natural polymer that is produced from the hydrolytic breakdown of collagen proteins and may be used to thicken aqueous solutions and form gels (Boran *et al*., 2010; Phillips & Williams, 2009). At 37˚C, mammalian gelatin reverts from its triple helix conformation to its coiled structure, melting reversibly into a solution (Somboon *et al*., 2014). Furthermore, maltodextrin is a polysaccharide that can be used in EN formulations. Different types of this polysaccharide are produced from the hydrolysis of starch and have a dextrose equivalent of less than 20 (Hofman *et al*., 2016). Variations in degree of esterification (DE) levels result in maltodextrins with a variety of physicochemical properties. While viscosity, cohesiveness, and coarse crystal prevention increase as DE decreases, hygroscopicity, solubility, osmolality, and the ability to lower the freezing point increase as DE increases. Because of strong gelation and water retention capabilities, maltodextrins are used as texture modifiers in the food industry. These gels exhibit limited elasticity, low mechanical stability, and a high turbidity .New food products can be developed by exploring different aspects of protein-polysaccharide interactions (Asiyanbi *et al*., 2017). Protein-polysaccharide interactions may impart to change the viscosity, texture, appearance and oral properties. Therefore, it is necessary to understand the mechanisms involved in protein-polysaccharide interactions and how these interactions alter during processing and storage (Neiser *et al*., 1999; Norton & Frith, 2001). Recent research has focused on the clinical effects of these formulations, but the structural and oral characteristics intended to attract consumers have not been thoroughly investigated. However, product design and appearance are effective tools for making products more appealing to patients and contributing to the commercial success of newly-formulated products. As the use of enteral nutrition formulas keeps growing, there is an urgent need for novel, consumer-oriented products. In order to promote patient acceptance and adherence, it is necessary to consider novel approaches to enteral nutrition formulation development. The purpose of the present investigation is to determine the impact of the ratio of gelatin to maltodextrin as well as the duration of storage on the turbidity, colorimetric, and sensory properties of the final product. An I-optimal combined design has been employed to optimize the sensory scores, appearance and color attributes.

Materials and Methods

The food-grade bovine skin gelatin type B (bloom 243) and maltodextrin-corn (DE = 10–14) were supplied by MEDA DIS TICARET (Turkey) and Zar Fructose (Iran), respectively. All experiments were carried out using distilled water.

- *Methods*

- *Stock solution preparation*

In order to produce gelatin (25 wt.%) and maltodextrin (30 wt.%) stock solutions, gelatin and maltodextrin powders were mixed, separately, with distilled water for 30 min At 60°C and

90°C, respectively, using a magnetic hotplate stirrer (Iran, M0D-F60). In order to prepare homogenous solutions, both stock solutions were briefly heated at 60°C prior to use. Appropriate amounts of the stock solutions were combined at 60°C to form binary systems (Beldengrün *et al*., 2020; Kasapis *et al*., 1993).

- *Color measurement*

Gels and dispersions were evaluated for color by HunterLab (USA, DP-9000). During the device's calibration procedure, standard white and black boards were utilized. Three color attributes including L*, a*, and b* were measured. L* represents the degree of luminance (0 is black and 100 is white). The red-green value denoted by a* is (positive value is red, negative value is green, and 0 is neutral color). The yellow-blue value represented by b* is 18 (a positive value indicates yellow, a negative value indicates blue, and a neutral value of 0 indicates a neutral color) (Dai *et al*., 2020). In this investigation, tests were conducted on samples at both 5°C and 37°C.

- *Turbidity measurement*

A turbidity meter (Taiwan, LUTRON TU-2016) with a light source of 850 nm was used to determine the amount of turbidity in NTU units at 37°C (Raja *et al*., 1989). The measurements accuracy was ±0.5 NTU.

- *Sensory evaluation*

Customers' acceptability was assessed by a panel of twenty untrained panelists. They included both students and employees from the Department of Food Technology. Before the sensory evaluation, samples were kept in the refrigerator, randomly marked, and served to panelists at 37°C with filtered water. Panelists evaluated color, odor, flavor, and overall acceptability on a 5-point hedonic scale as follows: 1) strongly dislike; 2) somewhat dislike; 3) neither like nor dislike 4) like it moderately; 5) like it a lot (Bulut & Candoğan, 2022; Jridi *et al*., 2015; Mutlu *et al*., 2018; Nhi *et al*., 2020).

- *Design and statistical analysis of experiments*

Design Expert 11.1.2 (Stat-Ease Inc.) was used for the statistical analysis. A mixed design and surface response technique were utilized to build a statistical model by analyzing the relationship between independent (gelatin and maltodextrin concentrations and time periods for product storage) and dependent variables (color, turbidity, and sensory evaluation). The combination design components, gelatin (A) and maltodextrin (B), had real values ranging from 4% to 7% and 1% to 4%, respectively. A time interval (C) ranging from 1 to 30 days was employed to develop a surface response approach. Table 1 displays the real and coded independent variables at various levels. Equation (1) illustrates the conventional form of the complete quadratic model as follows:

$$Y = \sum_{i=1}^{q} \beta_i X_i + \sum_{i<j}^{q} \sum \beta_{ij} X_i X_j \qquad (1)$$

where Y_1 (L^*- 5°C), Y_2 (L^*- 37°C), Y_3(a^*- 5°C),Y_4 (a^*- 37°C), Y_5(b^*- 5°C), Y_6 (b^*- 37°C), Y_7 (turbidity- 37°C), Y_8 (color), Y_9(odor), Y_{10} (flavor), Y_{11} (overall acceptability) are the predicted response; β_i and β_{ij} are linear and quadratic coefficients, respectively. The linear blending part is denoted by $\beta_i X_i$, and the excess response above the linear model is denoted by $\beta_{ij} X_i X_j$. This excess response is the result of the interaction between two components, which may either be antagonism (β_{ij} <0) or synergism (β_{ij}> 0). For developing the responses using response surface modeling (RSM), statistical data was used to fit a second-order polynomial equation (Equation 2) by making the necessary adjustments to account for the interaction between processing factors and the responses.

$$Y = \beta_0 + \sum_{j=1}^{k} \beta_j X_J + \sum_{i=1}^{k} \beta_{JJ} X_J^2 + \sum_{i=1}^{j-1} \sum_{j=i+1}^{k} \beta_{ij} X_i X_j + \varepsilon \qquad (2)$$

Where i and j represent the quadratic linear coefficient and the encoded independent variables, respectively; k is the number of investigated and optimized components, while 0 is a constant; i is the linear coefficient; j, ij, ji represents the linear, quadratic, and second-order interaction coefficients, respectively. There are also two independent variables, X i and X j, as well as corresponding errors (Table 1). The relevance of the model parameters was evaluated using a p-value that was set at 5 % (*p* <0 .05). Three replication tests were performed under ideal conditions for each answer to confirm the findings of optimization, and the outcomes of the experiment were compared with those predicted by optimization using the paired-t test. The model's fit was evaluated using F-value, p-value, R^2, lack of fit (LOF), acceptable precision, and CV% (Sabah *et al.*, 2021).

Table 1. Colorimetric, sensory and turbidity parameters for nineteen formulations using I-optimal combination design

RUN	A: Gelatin (%w/w)	B: Maltodextrin(%w/w)	C: Time (days)	Color						Turbidity NTU (37°C)	Sensory evaluation			
				L* (5°C)	L* (37°C)	a* (5°C)	a* (37°C)	b* (5°C)	b* (37°C)		Odor	Flavor	Color	overall acceptability
1	5.5	2.5	15.5	74.49	*75.1*	-2.14	-1.99	11.7	*11.38*	40.63	4	4.1	4.3	4
2	5.5	2.5	1	75.15	76.02	-1.5	-1.97	4.73	4.41	38.02	4.2	4.2	4.5	4.2
3	7	1	30	73.11	74.1	-2.12	-2.29	14.07	14	39	4	3.8	3.9	3.8
4	4.75	3.25	22.75	74.05	75.08	-2.09	-1.99	11.5	9.61	41.78	4.2	4.4	4.2	4.1
5	7	1	1	74.75	75.4	-1.6	-1.95	5.77	4.9	37.08	4	3.8	3.9	3.5
6	5.5	2.5	15.5	74.49	75.08	-1.99	-2.11	11.77	9.35	40.63	4.1	4.1	4.1	4
7	7	*1*	*15.5*	74.05	74.15	*-1.99*	-2.42	*12.39*	12.26	36.7	*4*	*3.8*	*4*	*3.7*
8	6.25	1.75	8.25	74.38	75.36	-2.07	-2.12	10.01	10.12	38.06	4.1	3.9	4	3.9
9	4	4	30	70.74	73.95	-1.57	-1.86	10.43	9.27	41.57	4.5	4.5	4.6	4.5
10	5.5	2.5	30	74.23	74.77	-2.42	-2.47	11.7	11.55	41.23	4	4.2	4	3.9
11	4.75	3.25	1	75.4	76.22	-1.34	-1.87	4.09	4.35	37.99	4.3	4.5	4.6	4.3
12	4.75	3.25	8.25	74.97	76.24	-1.78	-1.9	8.42	7.39	38.2	4.2	4.4	4.6	4.3
13	4	4	15.5	73.74	75.95	-1.47	-1.84	10.24	7.33	40.89	4.3	4.4	4.4	4.5
14	5.5	2.5	15.5	75	75.01	-2.14	-2.14	11.15	11.35	40.63	4	4	4.1	3.9
15	5.5	2.5	30	74.06	74.77	-2.4	-2.44	11.98	11.6	41.99	4.1	4.2	3.8	3.7
16	6.25	1.75	22.75	74.69	74.43	-2.27	-2.27	13.3	12.57	40.03	4	3.9	3.9	3.6
17	4	4	1	75.95	76.2	-1.1	-1.77	3.87	4.06	37.39	4.3	4.6	4.6	4.7
18	7	1	15.5	74.37	73.78	-1.99	-2.42	12.33	12.29	37.67	4	3.7	3.8	3.7
19	4	4	15.5	73.74	75.95	-1.51	-1.8	10.25	7.91	40.89	4.3	4.3	4.5	4.7

Results and Discussion

- *Color*

Food product acceptability is highly related to major quality characteristics such as color and transparency (Huang *et al*., 2018). Table 1 shows the color of gelatin-maltodextrin gel samples at 5 °C and after melting at 37 °C. L* (lightness), a* (greenness), and b* (yellowness) were investigated for gel and dispersions samples. As shown in Table 1, the values of L* in the states of gel and dispersion are 70.74-75.95 and 73.78-76.24, respectively. The lowest L* value was found at two different temperatures, 5°C and 37°C, with a gelatin to maltodextrin ratio of 4:4 and a storage time of 30 days (Figure 1 a,b).

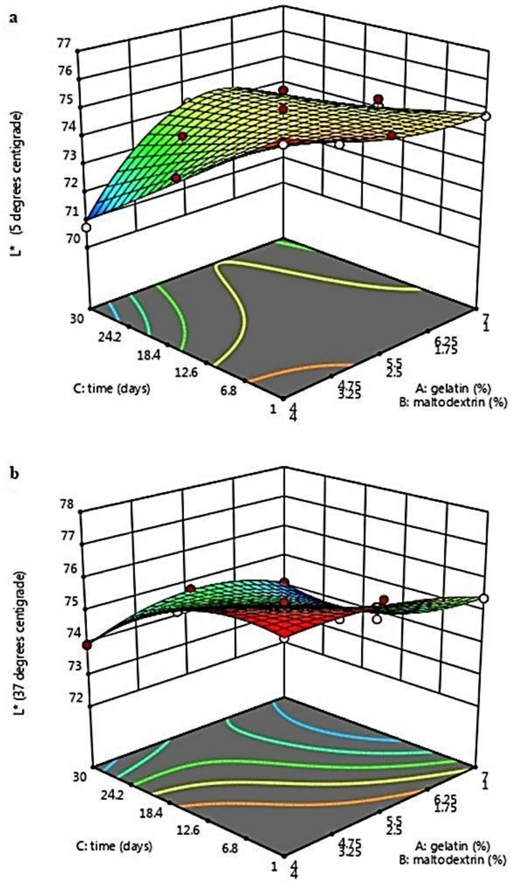

Fig. 1. Effect of storage time (days) and gelatin-to-maltodextrin ratio on L* at a) 5℃ b) 37℃.

Increasing the storage period and the amount of maltodextrin to gelatin appears to have resulted in a decrease in light scattering qualities in both gel and dispersion stages. Because maltodextrin solutions in water become less stable as the temperature drops to 4 °C (Chronakis, 2010) and cooling can result in the formation of gelatin clusters (Turgeon *et al*., 2003), it can be stated that in a gelatin and maltodextrin mixture system, the formation of the gel impedes the system's mobility and traps the maltodextrin inside the continuous gelatin matrix (Lorén & Hermansson, 2000). The formation of aggregates that scatter light is responsible for the decrease in transparency (Huang *et al*., 2018).These conditions will probably be reducing the trend's L* values.

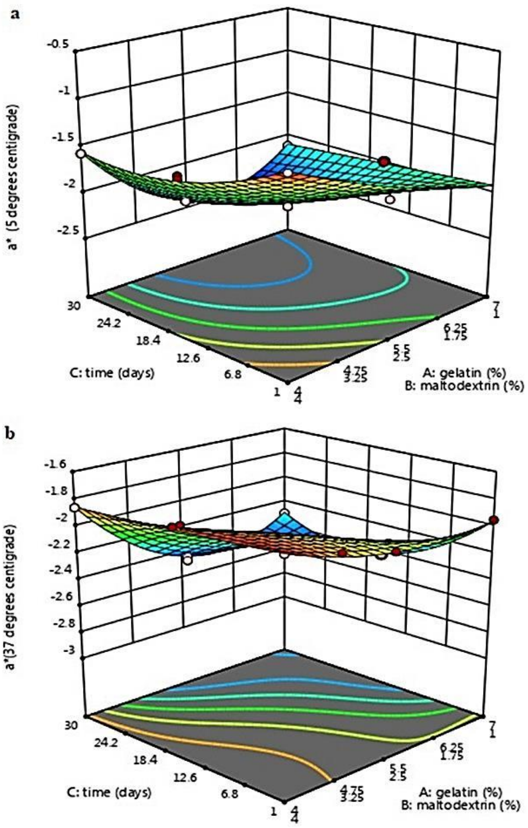

Fig. 2. Effect of storage time (days) and gelatin-to-maltodextrin ratio on a* at a) 5℃ b) 37℃.

All of the a* values were negative for all samples in gel or dispersion form. The range of a* values for the gel and dispersion states is -1.1 - -2.42 and -1.77 - -247, respectively, as shown in Table 1. After 30 days, it was observed that raising the maltodextrin to gelatin ratio had a substantial effect on the a* values of both the gel and dispersion states (Figure 2 a, b). All gel and dispersion samples have a*-values in green range, but those with the highest maltodextrin to gelatin ratios show a steady transition toward red. Gel formation reduces system mobility, inhibits large maltodextrin inclusions, and keeps them in the continuous gelatin matrix (Lorén *et al*., 2000). It seems that these conditions may cause developing a greener hue while also decreasing the lightness of samples. The data of positive b*values, indicated a preference toward yellow chroma. As shown in Table 1, the b* values in the gel states can range from 3.87 to 14.07 and from 4.06 to 14 in the dispersion states. Following 30 days of storage, the highest values of b* are found in the highest ratio of gelatin to maltodextrin in both gel and dispersion states (Figure 3(a, b)). Therefore, it is reasonable to conclude that the color of a ternary system consisting of gelatin, maltodextrin, and water is dependent on the ratio of biopolymer components and the period of time the system remains stable at 5°C. Due to the addition of maltodextrin to gelatin, the samples are less yellow with a tendency toward a green hue and a reduced lightness. Consequently, the results of the color test at 37 °C were nearly identical to those at 5 °C. However, it should be kept in mind that raw ingredients have an effect on the color of the gelatin, but this has no bearing on the nature or chemical quality of the gelatin itself. Also, imperfect filtration raises turbidity and influences L*, a*, and b* (Rahman & Jamalulail, 2013). The color coordinates of gelatin are affected by a number of variables, including animal origin, extraction method, and storage conditions. Gelatin is typically derived from different sources, including the skin and bone of pigs and cattle(Alipal *et al*., 2021; Sultana *et al*., 2018) and fish and other aquatic wastes (squid skin, swim bladder, and fish skins) (He *et al*., 2022; Karayannakidis & Zotos, 2016; Rawdkuen *et al*., 2013), which all may influence the color attributes of gelatin. On the other hand, the gelatin extraction method has a significant impact on the final product's color and quality(Ahmad *et al*., 2018; Ameer *et al*., 2017; Noor *et al*., 2021). Lastly, gelatin storage conditions following extraction may result in undesirable reactions, such as on-enzymatic browning reactions, and negatively impact the color quality (Ahmad *et al*., 2018; Sinthusamran *et al*., 2014).

- ***Turbidity***

The turbidity values can provide valuable insight into the properties and formation mechanisms of electrostatic complexes, which are primarily influenced by the electrostatic attraction between the existing polymers. In a mixed biopolymer system, phase separation frequently causes turbidity and the formation of light-scattering particles (Binsi *et al*., 2017). Table 1 shows the turbidity of maltodextrin and gelatin dispersions measured after melting at 37°C, which ranged from 36.7 to 41.99 NTU. The dispersions with the highest turbidity had a gelatin to maltodextrin ratio of (5.5:2.5) and (4.75:3.25), on days 15 and 22, respectively (Figure 4). This haze may arise as a result of the presence of high molecular weight, dextrinized molecules, which may be related to the type of starch

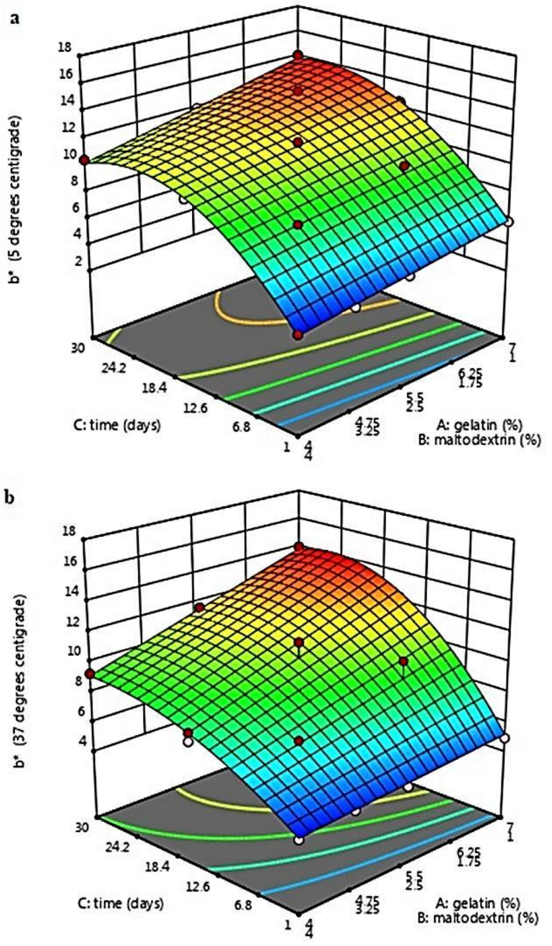

Fig. 3. Effect of storage time (days) and gelatin-to-maltodextrin ratio on b* at a) 5°C b) 37°C.

used to produce maltodextrin (Chronakis, 2010; Raja *et al.*, 1989). In contrast, various gelatin sources, such as animal skin and bones, exhibit distinct levels of turbidity after extraction. It has been observed that gelatin derived from animal skin has lower turbidity values than gelatin extracted from animal bones (Rahman & Jamalulail, 2013). The irregular aggregation of gelatin protein chains results in the random arrangement of gelatin molecules, producing a translucent gel with high turbidity (Ahmad *et al.*, 2021). As a result, the protein molecules may aggregate, and after cooling to 5°C, maltodextrin particles may become entrapped in the gelatin matrix, causing increased haze (Lorén & Hermansson, 2000). Kasapis, Morris, Norton, and Clark (1993) reported that the turbidity in gelatin-maltodextrin-mixed gels could be caused by a high level of helix-helix aggregation within the molecules. Butler and Heppenstall-Butler (2001) also accomplished the turbidity measurements and the effect of adding maltodextrin to gelatin. According to the findings of their study, lower quench temperatures lead to greater turbidities. In another investigation involving gelatin/dextran mixtures, a significant increase in the level of dispersed light and turbidity was observed as soon as the temperature declined below 20 °C (Butler & Heppenstall-Butler, 2001, 2003). The turbidity of gelatin-polysaccharide systems varies depending on the type of polysaccharide (Asiyanbi *et al.*, 2017). The formation of a polymer network of light-scattering particles during the cooling process causes the turbidity of a gelatin-gum (xanthan/tragacanth) system to increase proportionally with the quantity of gum present, according to recent studies (Binsi *et al.*, 2017).

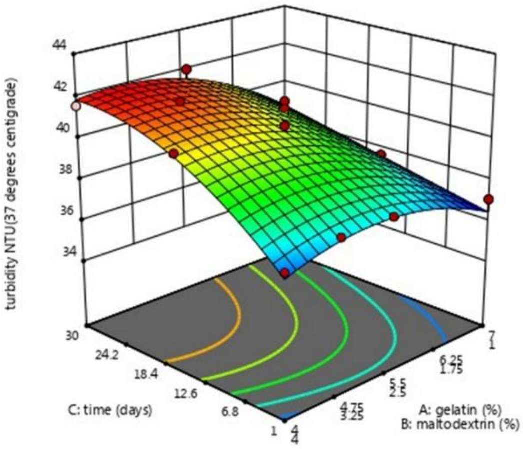

Fig. 4. Effect of storage time (days) and gelatin-to-maltodextrin ratio on turbidity.

- *Sensory evaluation*

Sensory assessment provides essential information on how a product or experience influences sensory perception, leading to emotional, intellectual, and behavioral responses (Delarue, 2022). It is often used for ensure quality control during the manufacturing process and to develop new products and services (Feiner, 2006).

Table 1 displays the flavor, color, odor, and overall acceptance scores for dispersion gelatin-maltodextrin, with the scores in ranges of 4-4.5, 3.7-4.6, 3.8-4.8, and 3.5-4.7, respectively. Figures 5 (a, b, c, and d) display the results of sensory evaluation during 30-day storage.

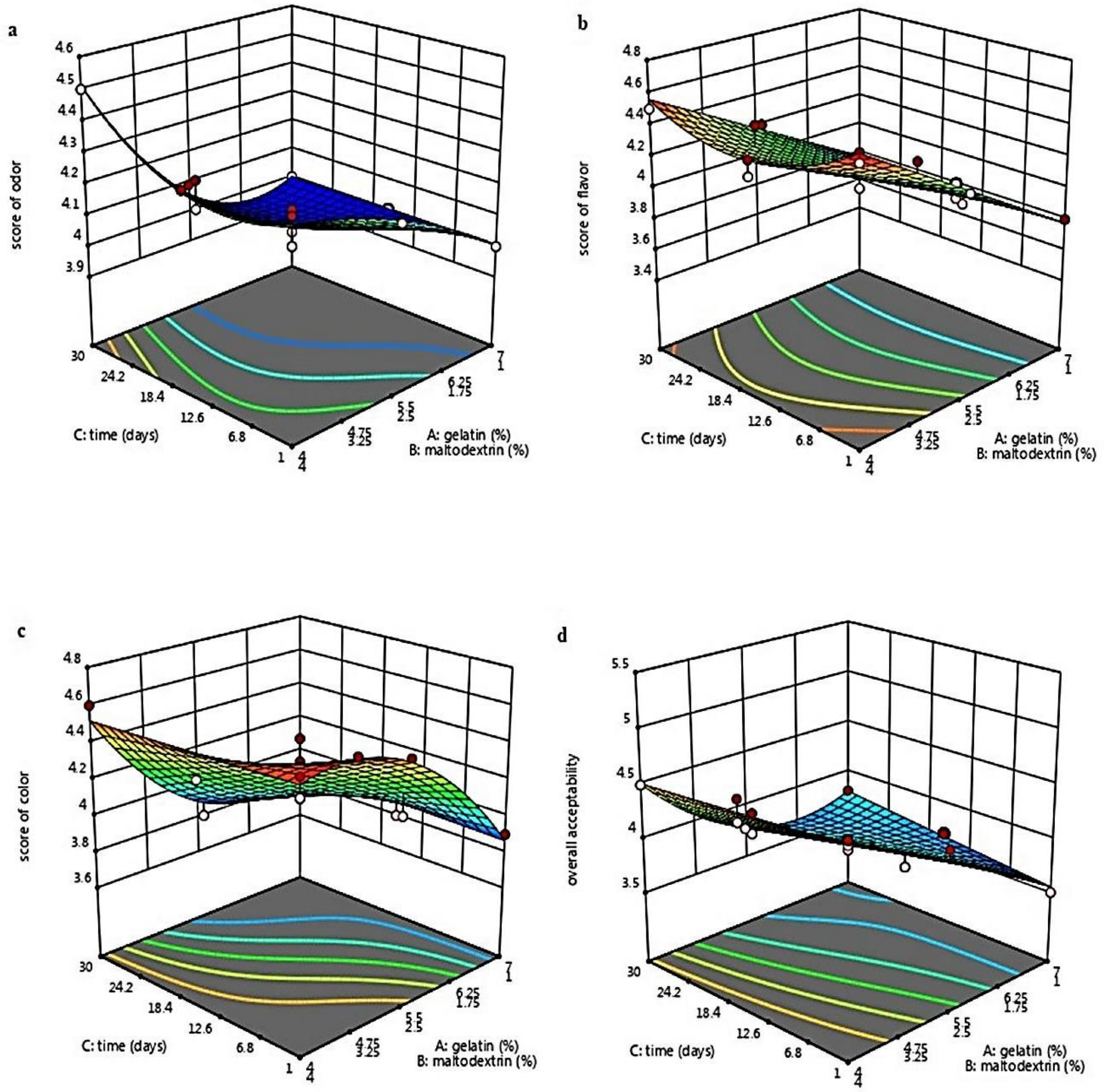

Fig. 5. Effect of storage time (days) and gelatin-to-maltodextrin ratio on sensory properties.

During the storage period, the samples coded 11, 13, and 17 had the best odor score. A gelatin-to-maltodextrin ratio of 4:4 (run 17) also yielded the best flavor score. Taste and the individual's evaluation of the taste have a significant impact on how people perceive flavor and other item attributes (Dürr, 1994). In this study, bovine skin gelatin typically has a distinct odor, whereas maltodextrin solutions are pleasantly smooth and tasteless (Chronakis, 2010; Ninan et al., 2014). Flavours vary in composition, while the panelists often have differing sensitivities, expectations, and experiences that can influence their judgment and evaluation. These factors, among others, have contributed to the variability of results(Dürr, 1994).After 30 days of storage, the gelatin-to-maltodextrin ratios of 4:4 and 4.75:3.25 (runs 9, 11, 12, and 17) achieved the highest color score. Light scattering and pigmentation, which influence opacity and translucency in addition to color, interact with the structure of the food to determine its appearance(MacDougall, 2003).Commercial gelatin solutions range in color from pale yellow to dark amber (Cole & Roberts, 1997). The maltodextrin used in this research has a DE of 10 to 14. It has a retrograde tendency and causes cloudiness (John, 1999). The gelatin-maltodextrin dispersion frequently appears white, foggy, with a yellow hue. The dispersion with a 4:4 ratios (run 17) achieved the highest overall acceptability during the storage period. It should be noted that, because these dispersions are intended to be used as a nutrition supplement for patients, the odorless and tasteless nature, as well as the mild color, may be considered as an advantage and provide the potential to be adjusted with consumers' preference.

- *Goodness of fit models*

The presented data in Table 1 comprises the 19-run I-optimal combined experimental design and corresponding response values. Tables 2 and 3 exhibit the model type, estimated parameters, and variance analysis for each model proposed for all responses. All responses exhibited R^2 values exceeding 0.90, and a significant correlation was observed between the experimental and predicted values. The statistical analysis revealed that there was no significant lack of fit for all responses ($p > 0.05$). The signal-to-noise ratio varied from 12.58 to 61.27, validating the models. Table 4 shows the model equations for each response.

Optimization

The optimization technique was successfully carried out while taking into account the targeted levels for each group of responses as follows: maximum scores for sensory properties (odor (close to 4.5), flavor (close to 4.6), color (close to 4.6), and overall acceptability (close to 4.7)), and turbidity in the range of (36.7-41.99 NTU). The target levels for instrumental color characteristics were also considered in range: L*[@ 5℃ and 37℃ (70.74-75.95 and 73.78-76.24), respectively], a*[@ 5℃ and 37℃ (-1.1 to - 2.42 and -1.77 to -2.47), respectively] and b*[@ 5℃ and 37℃ (3.87 -14.07 and 4.06 - 14), respectively]. The optimum amounts of gelatin, maltodextrin, and time were 4.026: 3.974% w/w, and 10.8 (day), respectively, with an overall desirability of 0.7. The verification of the optimal conditions' validity was achieved through a comparison between the predicted and experimental values for each response (Table 5).

Table 2. Model fitting for colorimetric test at 5℃ and 37 ℃

Source	Mixture × Process	F-value	p-value	R^2	R^2 Adj	R^2 pred	Adeq Precision	C.V. %
$\boldsymbol{L*}$ (**5**℃)								
Model	Quadratic × Linear	65.97	< 0.0001	0.9621	0.9475	0.8791	37.22	0.33
Lack of Fit		1.45	0.3547					
$\boldsymbol{L*}$ (**37**℃)								
Model	Quadratic × Quadratic	55.61	< 0.0001	0.9780	0.9604	0.8283	20.90	0.21
Lack of Fit		2.57	0.1620					
$\boldsymbol{a*}$ (**5**℃)								
Model	Quadratic × Quadratic	84.20	< 0.0001	0.9787	0.9671	0.9183	30.94	3.68
Residual								
Lack of Fit		1.92	0.2459					
$\boldsymbol{a*}$ (**37**℃)								
Model	Quadratic × Quadratic	48.65	< 0.0001	0.9750	0.9549	0.7465	19.47	2.40
Residual								
Lack of Fit		0.8101	0.5886					
$\boldsymbol{b*}$ (**5**℃)								
Model	Linear × Quadratic	408.35	< 0.0001	0.9937	0.9912	0.9822	61.27	2.93
Residual								
Lack of Fit		1.94	0.2419					
$\boldsymbol{b*}$ (**37**℃)								
Model	Linear × Quadratic	74.08	< 0.0001	0.9661	0.9530	0.9406	25.60	7.30
Residual								
Lack of Fit		0.6624	0.7124					

Table 3. Model fitting for turbidity and sensory scores at 37 ℃

Source	Mixture × Process	F-value	p-value	R^2	R^2 Adj.	R^2 pred.	Adeq. Precision	C.V. %
Turbidity NTU (**37**℃)								
Model	Quadratic × Quadratic	33.03	< 0.0001	0.9270	0.8989	0.8201	17.05	1.43
Lack of Fit		2.78	0.1378					
Sensory evaluation Scores								
Odor								
Model	Quadratic × Quadratic	40.31	< 0.0001	0.9527	0.9291	0.8433	21.89	0.96
Lack of Fit		0.455	0.8330					
Flavor								
Model	Linear × Quadratic	93.08	< 0.0001	0.9490	0.9388	0.9006	27.84	1.66
Lack of Fit		1.62	0.3094					
Color								
Model	Quadratic × Linear	28.14	< 0.0001	0.9154	0.8829	0.8065	12.58	2.43
Lack of Fit		0.555	0.7812					
Overall acceptability								
Model	Quadratic × Linear	62.42	< 0.0001	0.9600	0.9446	0.9121	22.90	2.12
Lack of Fit		0.6642	0.7113					

Table 4. Model equations for each response

Response	Equation
$\boldsymbol{L*}$ (**5**℃)	$74.05\,A + 73.57\,B + 3.39\,AB - 0.7797AC - 2.58BC + 5.19\,ABC$
$\boldsymbol{L*}$ (**37**℃)	$73.99A + 75.97\,B + 0.6894\,AB - 0.6708\,AC - 1.14\,BC + 0.7987\,ABC + 0.7706AC^2 - 0.8950BC^2 + 1.41ABC^2$
$\boldsymbol{a*}$ (**5**℃)	$-2.01\,A - 1.53\,B - 1.36AB - 0.0936\,AC - 0.2343\,BC - 1.02\,ABC + 0.2075\,BC^2$
$\boldsymbol{a*}$ (**37**℃)	$-2.41\,A - 1.82\,B + 0.2117\,AB - 0.1634\,AC - 0.0448\,BC - 0.5112\,ABC + 0.2940\,AC^2 + 0.0085\,BC^2 - 1.17\,ABC^2$
$\boldsymbol{b*}$ (**5**℃)	$12.60\,A + 10.31\,B + 4.00\,AC + 3.20\,BC - 2.75\,AC^2 - 3.34\,BC^2$
$\boldsymbol{b*}$ (**37**℃)	$12.78\,A + 7.88\,B + 4.34\,AC + 2.50BC - 3.28\,AC^2 - 1.25\,BC^2$
Turbidity NTU (**37**℃)	$37.62\,A + 40.71B + 4.79\,AB + 1.16\,AC + 2.38\,BC - 1.24\,BC^2$
Score of odor	$4.00\,A + 4.29\,B - 0.3331\,AB - 0.0016\,AC + 0.0983\,BC - 0.5213\,ABC + 0.1231\,BC^2$
Score of flavor	$3.78\,A + 4.39\,B - 0.0473\,BC + 0.2116BC^2$
Score of color	$3.88\,A + 4.54\,B - 0.1291\,AB + 0.0169\,AC - 0.0213BC - 1.20ABC$
overall acceptability	$3.68A + 4.59\,B - 0.7031\,AB + 0.1234\,AC - 0.0742\,BC - 0.8450ABC$

Table 5. The findings of the validity examination of optimum condition

Response	Predicted value	Experimental value	*p*-value (paired-*t* test)
L* (5°C)	74.41 ± 0.12	74.2 ± .82	0.57
L* (37°C)	76.23 ± 0.16	76.30 ± 0.73	0.9
a* (5°C)	-1.44 ± 0.069	-1.47 ± 0.039	0.73
a* (37°C)	-1.80 ± 0.05	-1.88 ± 0.17	0.59
b* (5°C)	8.94 ± 0.29	9.02 ± 0.54	0.92
b* (37°C)	6.98 ± 0.6	7.36 ± 0.39	0.55
Turbidity NTU (37°C)	39.83 ± 0.56	40.07 ± 2.77	0.91
Score of odor	4.26 ± 0.03	4.28 ± 0.2	0.86
Score of flavor	4.42 ± 0.06	4.45 ± 0.32	0.91
Score of color	4.54 ± 0.1	4.58 ± 0.48	0.92
overall acceptability	4.59 ± 0.08	4.49 ± 0.26	0.47

Conclusion

The study highlights the feasibility of using a binary biopolymer system composed of gelatin and maltodextrin as a beneficial technique for nutritional control in people with limited dietary options due to chronic illnesses, surgical procedures, dysphagia, and diminished appetite. According to the findings of this study, the storage duration and gelatin and maltodextrin concentrations have a significant impact on the final product's color, turbidity, and sensory properties. The inclusion of maltodextrin to formulations decreases the clarity and transparency. The values of a* and b* indicate a shift in the color spectrum towards yellow and green, respectively, highlighting the impact of maltodextrin in this system. According to the results of the sensory analysis, the increased ratio of maltodextrin to gelatin has been favorably received by sensory panelists, as evidenced by the increase in positive feedback regarding this product. Analyzing the color attributes, turbidity, and sensory evaluations of a semi-solid enteral nutrition formula was a new approach applied in this study. Sensory and color analyses are critical methods for evaluating the quality of semi-solid enteric formulations.

Because the gelatin-maltodextrin mixture is odorless and tasteless, it can be utilized to make functional foods. The efficiency of this structure could be increased by using the microencapsulation technique including flavoring agents and antioxidants. More physiological benefits can be provided to the consumer in this manner as well.

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References

Ahmad, T., Ismail, A., Ahmad, S. A., Khalil, K. A., Awad, E. A., Akhtar, M. T. & Sazili, A. Q. (2021). Recovery of Gelatin from Bovine Skin with the Aid of Pepsin and Its Effects on the Characteristics of the Extracted Gelatin. Polymers, Vol. 13, Page 1554, 13(10), 1554. https://doi.org/10.3390/POLYM13101554

Ahmad, T., Ismail, A., Ahmad, S. A., Khalil, K. A., Leo, T. K., Awad, E. A., Imlan, J. C. & Sazili, A. Q. (2018). Effects of Ultrasound Assisted Extraction in Conjugation with Aid of Actinidin on the Molecular and Physicochemical Properties of Bovine Hide Gelatin. Molecules : A Journal of Synthetic Chemistry and Natural Product Chemistry, 23(4). https://doi.org/10.3390/MOLECULES2304073

0

Alipal, J., Mohd Pu’ad, N. A. S., Lee, T. C., Nayan, N. H. M., Sahari, N., Basri, H., Idris, M. I. & Abdullah, H. Z. (2021). A review of gelatin: Properties, sources, process, applications, and commercialisation. Materials Today: Proceedings, 42, 240–250. https://doi.org/10.1016/J.MATPR.2020.12.922

Ameer, K., Bae, S. W., Jo, Y., Lee, H. G., Ameer, A. & Kwon, J. H. (2017). Optimization of microwave-assisted extraction of total extract, stevioside and rebaudioside-A from Stevia rebaudiana (Bertoni) leaves, using response surface methodology (RSM) and artificial neural network (ANN) modelling. Food Chemistry, 229, 198–207. https://doi.org/10.1016/J.FOODCHEM.2017.01.121

Asiyanbi, T. T., Bio-Sawe, W., Idris, M. A. & Hammed, A. M. (2017). Gelatin-polysaccharide based materials: A review of processing and properties. International Food Research Journal, 24(December), 313–319.

Beldengrün, Y., Dallaris, V., Jaén, C., Protat, R., Miras, J., Calvo, M., García-Celma, M. J. & Esquena, J. (2020). Formation and stabilization of multiple water-in-water-in-water (W/W/W) emulsions. Food Hydrocolloids, 102, 105588. https://doi.org/10.1016/J.FOODHYD.2019.105588

Binsi, P. K., Nayak, N., Sarkar, P. C., Joshy, C. G., Ninan, G. & Ravishankar, C. N. (2017). Gelation and thermal characteristics of microwave extracted fish gelatin–natural gum composite gels. Journal of Food Science and Technology, 54(2), 518–530. https://doi.org/10.1007/s13197-017-2496-9

Boran, G., Mulvaney, S. J. & Regenstein, J. M. (2010). Rheological Properties of Gelatin from Silver Carp Skin Compared to Commercially Available Gelatins from Different Sources. Journal of Food Science, 75(8), E565–E571. https://doi.org/10.1111/J.1750-3841.2010.01543.X

Boullata, J., Brantley, S., Corkins, M., Guenter, P., Krenitsky, J., Lyman, B., Metheny, N. A., Mueller, C., Robbins, S. & Wessel, J. (2009). ASPEN enteral nutrition practice recommendations. Naspghan.Org. https://doi.org/10.1177/0148607108330314

Bulut, E. G. & Candoğan, K. (2022). Development and characterization of a 3D printed functional chicken meat based snack: Optimization of process parameters and gelatin level. LWT, 154. https://doi.org/10.1016/j.lwt.2021.112768

Butler, M. F. & Heppenstall-Butler, M. (2001). Phase Separation in Gelatin/Maltodextrin and Gelatin/Maltodextrin/Gum Arabic Mixtures Studied Using Small-Angle Light Scattering, Turbidity, and Microscopy. Biomacromolecules, 2 (3), 812–823. https://doi.org/10.1021/BM015503R

Butler, M. F. & Heppenstall-Butler, M. (2003). Phase separation in gelatin/dextran and gelatin/maltodextrin mixtures. Food Hydrocolloids, 17(6), 815–830. https://doi.org/10.1016/S0268-005X(03)00103-6

Chronakis, I. S. (2010). On the Molecular Characteristics, Compositional Properties, and Structural-Functional Mechanisms of Maltodextrins: A Review. Http://Dx.Doi.Org/10.1080/10408699891274327, 38 (7), 599–637. https://doi.org/10.1080/10408699891274327

Cole, C. G. B. & Roberts, J. J. (1997). Gelatine colour measurement. Meat Science, 45(1), 23–31. https://doi.org/10.1016/S0309-1740(96)00096-4

Dai, H., Li, X., Du, J., Ma, L., Yu, Y., Zhou, H., Guo, T. & Zhang, Y. (2020). Effect of interaction between sorbitol and gelatin on gelatin properties and its mechanism under different citric acid concentrations. Food Hydrocolloids, 101, 105557. https://doi.org/10.1016/J.FOODHYD.2019.105557

Delarue, J. (2022). Overview of sensory methods for the evaluation of nonfood products. Nonfood Sensory Practices, 17–37. https://doi.org/10.1016/B978-0-12-821939-3.00020-8

Dürr, P. (1994). Sensory analysis of flavours. Understanding Natural Flavors, 21–28. https://doi.org/10.1007/978-1-4615-2143-3_2

Feiner, G. (2006). Sensory evaluation of meat products. Meat Products Handbook, 565–

568. https://doi.org/10.1533/9781845691721.3.565

He, J., Zhang, J., Xu, Y., Ma, Y. & Guo, X. (2022). The Structural and Functional Differences between Three Species of Fish Scale Gelatin and Pigskin Gelatin. Foods, 11, 3960, 11(24), 3960. https://doi.org/10.3390/FOODS11243960

Hofman, D. L., van Buul, V. J. & Brouns, F. J. P. H. (2016). Nutrition, Health, and Regulatory Aspects of Digestible Maltodextrins. Critical Reviews in Food Science and Nutrition, 56(12), 2091–2100. https://doi.org/10.1080/10408398.2014.940415

Huang, T., Tu, Z. C., Shangguan, X., Wang, H., Zhang, N., Zhang, L. & Sha, X. (2018). Gelation kinetics and characterization of enzymatically enhanced fish scale gelatin–pectin coacervate. Journal of the Science of Food and Agriculture, 98(3), 1024–1032. https://doi.org/10.1002/JSFA.8551

John, M. (1999). Principles of Food Chemistry Third Edition. In Science. http://www.knovel.com/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=1093

Jridi, M., Abdelhedi, O., Souissi, N., Kammoun, M., Nasri, M. & Ayadi, M. A. (2015). Improvement of the physicochemical, textural and sensory properties of meat sausage by edible cuttlefish gelatin addition. Food Bioscience, 12, 67–72. https://doi.org/10.1016/j.fbio.2015.07.007

Kanie, J., Suzuki, Y., Akatsu, H., Kuzuya, M. & Iguchia, A. (2004). Prevention of late complications by half-solid enteral nutrients in percutaneous endoscopic gastrostomy tube feeding. Gerontology, 50(6), 417–419. https://doi.org/10.1159/000080181

Karayannakidis, P. D. & Zotos, A. (2016). Fish Processing By-Products as a Potential Source of Gelatin: A Review. Journal of Aquatic Food Product Technology, 25(1), 65–92. https://doi.org/10.1080/10498850.2013.827767

Kasapis, S., Morris, E. R., Norton, I. T. & Clark, A. H. (1993). Phase equilibria and gelation in gelatin/maltodextrin systems - Part II: composition-dependence of mixed-gel moduli. Carbohydrate Polymers, 21(4), 269–276. https://doi.org/10.1016/0144-8617(93)90058-C

Lesser, M. N. R. & Lesser, L. I. (2021). Nutrition Support Therapy. American Family Physician, 104(6), 580–588. https://doi.org/10.1007/978-3-642-00418-6_3226

Limketkai, B. N., Shah, N. D., Sheikh, G. N. & Allen, K. (2019). Classifying Enteral Nutrition: Tailored for Clinical Practice. Current Gastroenterology Reports, 21(9). https://doi.org/10.1007/S11894-019-0708-3

Lorén, N., Hermansson, A. M., Williams, M. A. K., Lundin, L., T. J., Foster, C. D., Hubbard, A. H., Clark, I. T., Norton, E. T., Bergström, A, & Goodall, D. M. (2000). Phase Separation Induced by Conformational Ordering of Gelatin in Gelatin/Maltodextrin Mixtures. Macromolecules, 34(2), 289–297. https://doi.org/10.1021/MA0013051

Lorén, N. & Hermansson, A. M. (2000). Phase separation and gel formation in kinetically trapped gelatin/maltodextrin gels. International Journal of Biological Macromolecules, 27(4), 249–262. https://doi.org/10.1016/S0141-8130(00)00127-6

MacDougall, D. B. (2003). SENSORY EVALUATION | Appearance. Encyclopedia of Food Sciences and Nutrition, 5161–5167. https://doi.org/10.1016/B0-12-227055-X/01066-X

Mutlu, C., Tontul, S. A. & Erbaş, M. (2018). Production of a minimally processed jelly candy for children using honey instead of sugar. LWT, 93, 499–505. https://doi.org/10.1016/J.LWT.2018.03.064

Nagai, K., Fukuno, S., Moriwaki, R., Kuroda, H., Omotani, S., Miura, T., Hatsuda, Y., Myotoku, M. & Konishi, H. (2022). Influence of concurrent and staggered dosing of semi-solid nutrients on the pharmacokinetics of orally administered carbamazepine in rats. Die Pharmazie, 77(3), 118–120. https://doi.org/10.1691/2022.1756

Neiser, S., Draget, K. I. & Smidsrød, O. (1999). Interactions in bovine serum albumin-calcium alginate gel systems. Food Hydrocolloids, 13 (6), 445–458. https://doi.org/10.1016/S0268-005X(99)00019-3

Nhi, T. T. Y., Vu, N. D., Quyen, N. N.,

Thinh, P. V., Tho, N. T. M. & Truc, T. T. (2020). The effect of malt, pectin, and gelatin concentrations on elasticity, color and sensory evaluation of soursop (Annona muricata L.) jelly candy. IOP Conference Series: Materials Science and Engineering, 991 (1). https://doi.org/10.1088/1757-899X/991/1/012013

Ninan, G., Joseph, J. & Aliyamveettil, Z. A. (2014). A comparative study on the physical, chemical and functional properties of carp skin and mammalian gelatins. Journal of Food Science and Technology, 51 (9), 2085. https://doi.org/10.1007/S13197-012-0681-4

Noor, N. Q. I. M., Razali, R. S., Ismail, N. K., Ramli, R. A., Razali, U. H. M., Bahauddin, A. R., Zaharudin, N., Rozzamri, A., Bakar, J. & Shaarani, S. M. (2021). Application of Green Technology in Gelatin Extraction: A Review. Processes, 9 (12), 2227. https://doi.org/10.3390/PR9122227

Norton, I. T. & Frith, W. J. (2001). Microstructure design in mixed biopolymer composites. Food Hydrocolloids, 15 (4–6), 543–553. https://doi.org/10.1016/S0268-005X(01)00062-5

Okabe, K., Kaneko, R., Kawai, T., Ohta, Y., Ohara, G. & Hibi, H. (2022). Efficacy of semi-solidification of enteral nutrients for postoperative nutritional management with a nasogastric tube. Nagoya Journal of Medical Science, 84 (2), 366–373. https://doi.org/10.18999/NAGJMS.84.2.366

Ong, C. S., Yesantharao, P., Brown, P. M., Canner, J. K., Brown, T. A., Sussman, M. S. & Whitman, G. J. R. (2021). Nutrition Support After Cardiac Surgery: Lessons Learned From a Prospective Study. Seminars in Thoracic and Cardiovascular Surgery, 33 (1), 109–115. https://doi.org/10.1053/J.SEMTCVS.2020.06.043

Phillips, G. O. & Williams, P. A. (2009). Handbook of Hydrocolloids: Second Edition. In Handbook of Hydrocolloids: Second Edition. https://doi.org/10.1533/9781845695873

Rahman, M. N. A. & Jamalulail, S. A. S. K. A. (2013). Extractions, Physicochemical Characterizations And Sensory Quality Of Chicken Feet Gelatin. Borneo Science, March, 33–43.

Raja, K. C. M., Sankarikutty, B., Sreekumar, M., Jayalekshmy, A. & Narayanan, C. S. (1989). Material Characterization Studies of Maltodextrin Samples for the Use of Wall Material. Starch - Stärke, 41 (8), 298–303. https://doi.org/10.1002/STAR.19890410805

Rawdkuen, S., Thitipramote, N. & Benjakul, S. (2013). Preparation and functional characterisation of fish skin gelatin and comparison with commercial gelatin. International Journal of Food Science & Technology, 48 (5), 1093–1102. https://doi.org/10.1111/IJFS.12067

Sabah, S., Sharifan, A., Akhonzadeh Basti, A., Jannat, B. & TajAbadi Ebrahimi, M. (2021). Use of D-optimal combined design methodology to describe the effect of extraction parameters on the production of quinoa–barley malt extract by superheated water extraction. Food Science & Nutrition, 9 (4), 2147–2157. https://doi.org/10.1002/FSN3.2184

Sinthusamran, S., Benjakul, S. & Kishimura, H. (2014). Characteristics and gel properties of gelatin from skin of seabass (Lates calcarifer) as influenced by extraction conditions. Food Chemistry, 152, 276–284. https://doi.org/10.1016/j.foodchem.2013.11.109

Somboon, N. & Karrila, T. (2014). Properties of gels from mixed agar and fish gelatin. Search.Proquest.Com.https://search.proquest.com/openview/374c7615b456aed410c0accee64a3dda/1?pq-origsite=gscholar&cbl=816390

Sultana, S., Hossain, M. A. M., Zaidul, I. S. M. & Ali, M. E. (2018). Multiplex PCR to discriminate bovine, porcine, and fish DNA in gelatin and confectionery products. LWT, 92, 169–176. https://doi.org/10.1016/J.LWT.2018.02.019

Turgeon, S. L., Beaulieu, M., Schmitt, C. & Sanchez, C. (2003). Protein–polysaccharide interactions: phase-ordering kinetics, thermodynamic and structural aspects. Current Opinion in Colloid & Interface Science, 8 (4–5), 401–414. https://doi.org/10.1016/S1359-0294(03)00093-1