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Correlation between physical properties and sensory evaluation of extruded Phyto-snack

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ABSTRACT

Background: Snack products are ubiquitous in modern dietary habits, and their sensory attributes play a critical role in consumer preferences. The texture of snacks is characterized by fracturability, hardness, and chewiness which influences consumer's acceptance. This study focused on investigating the interplay between the physical properties of an extruded snack product and its sensory attributes.

Objectives: This present study aimed to explore the potential correlations between these texture profiles and sensory attributes.

Methods: Texture profile analysis was employed to measure the snack's fracturability, hardness, and chewiness. A panel of 100 participants was engaged in sensory evaluation, using a hedonic scale to rate the snack's attributes. Pearson's correlation coefficient was employed to investigate potential associations between the texture profile and sensory attributes.

Results: The physical properties, including fracturability (35.266±0.58 N), hardness (52.611±0.73 N), and chewiness (15.89±3.36) were determined through Texture Profile Analysis (TPA). Concurrently, sensory attributes were evaluated by a panel of 100 untrained assessors. The sensory ratings for fracturability (4.58±0.87), hardness (4.21±0.98), chewiness (3.87±1.25), appearance (4.30±1.06), overall tasting (4.15±0.61), overall liking (4.56±0.94), and overall acceptance (4.40±1.31) provide valuable insights into the product's sensory appeal. The correlation values between the TPA data and sensory were attributes of the extruded snack product. Pearson's correlation coefficients revealed significant relationships between physical properties and sensory attributes. Notably, fracturability exhibited a strong positive correlation with fracturability in sensory evaluation (r = 0.776, $p < 0.05$). Similarly, hardness demonstrated moderate positive correlations with both fracturability (r = 0.452, $p < 0.05$) and chewiness (r = 0.687, $p < 0.05$), while chewiness was moderately correlated with fracturability (r = 0.634, $p < 0.05$) and hardness (r = 0.769, $p < 0.05$).

Conclusion: The findings revealed valuable insights into the food industry, emphasizing optimizing texture characteristics to enhance snack products' sensory appeal and satisfy consumer preferences. Further study in this domain may explore additional factors influencing sensory perception and refine the snack's textual attributes for enhanced consumer satisfaction.

Keywords: Extruded phyto-snack, Physical properties, Sensory evaluation

1. Introduction

The evaluation of food products is a complex and multifaceted process that involves the assessment of various physical properties and sensory attributes. Sensory evaluation, in particular is a fundamental aspect of food science, as it provides valuable insights into the organoleptic qualities of a product including its taste, aroma, texture, and overall acceptability [1].

One specific category of snack foods that has gained considerable attention recently is extruded snacks, typically made from various ingredients including grains, legumes, and other plant-based materials [2]. Extrusion is a widely employed processing technique in the food industry because it transforms raw materials into convenient, shelf-stable snack products [3]. Extruded snacks have become increasingly popular, especially among health-conscious consumers as they offer a convenient and flavorful way to incorporate plant-based ingredients into their diets [4].

Phyto-snacks are a specific type of extruded snack known for using plant-based ingredients, often emphasizing their health and sustainability attributes. To comprehensively assess the quality and consumer appeal of Phyto-snacks, examining their physical characteristics (e.g. moisture content, hardness, color, and density) and sensory attributes (e.g. taste, aroma, texture, and overall liking) is essential. For several reasons understanding the correlation between these physical properties and sensory evaluation are important such as; (1) allows for optimizing production processes and enabling manufacturers to produce snacks that meet consumer expectations consistently (2) identify the key sensory attributes that drive consumer preferences, guiding product reformulation and marketing strategies, and (3) contribute to the broader discourse on the development of healthier and more sustainable snack options, aligning with the evolving dietary preferences of contemporary consumers [5].

The findings of this study would shed light on the factors contributing to the sensory appeal of these snacks, thereby facilitating their development, commercialization, and potential contribution to healthier and more sustainable food choices.

2. Methods

2.1. Sample preparation and extrusion experiment

The samples were developed using powdered phyto ingredients sourced from fruits and vegetables. Formulations containing a

minimum of 42% functional ingredients were prepared for extrusion processing. These formulations blended specific food components including phyto powder from fruits and vegetables, binders, defatted soy flour (DFSF), maltodextrin, and rice bran oil.

Extrusion experiments were conducted using a twin-screw extruder. A twin-screw volumetric feeder introduced the dry mixture into the extruder. The following process conditions were applied: a screw speed of 400 rpm. The barrel was divided into two zones: the first heated to 70°C (from feed entry to midpoint) and the second to 120°C (from middle to die exit pressure). After extrusion, the samples were cooled for 30 minutes and packaged in aluminum foil bags then after stored at room temperature for later determination.

2.2 Physical Properties Testing

A texture analyzer was used to determine the texture of extruded phyto-snack samples. The method involved subjecting the samples to controlled forces (Figure 1.) and measuring their responses to determine properties like fracturability, hardness, cohesiveness, springiness, and chewiness (Table1). The analysis objectively measured the extruded snack's physical texture characteristics.

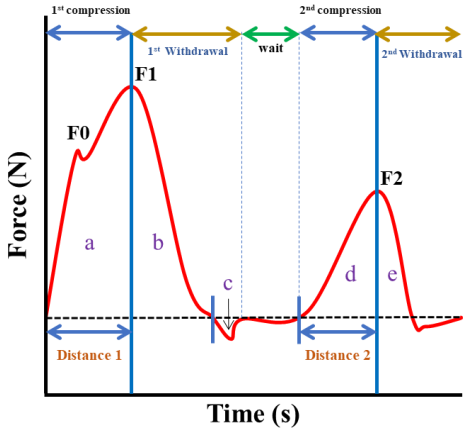

Figure 1: Graph of texture profile analysis [6]

Table 1: Definition of texture profile analysis [6-7]

Texture profile	Calculation	Definition
Fracturability (N)	F0	The first significant peak in the first compression.
Hardness (N)	F1	The highest peak force was measured during the first compression.
Cohesiveness	(d+e)/(a+b)	The area underneath the second compression curve is divided by the area underneath the first.
Springiness (%)	(Distance 2)/(Distance 1)*100	A ratio or percentage of a product's recovery to its original height.
Chewiness (N)		Hardness x Cohesiveness x Springiness.

2.3 Sensory Evaluation

Sensory evaluation was conducted at Khon Kaen University involving a diverse panel of 100 untrained individuals representing both genders within the age range of 6 to 12 years. The ethical approval for this analysis was taken from the Research Ethics Committee of Khon Kaen University (Approval ID: HE652038). A five-point hedonic scale was employed to gauge consumer preferences and perspectives, encompassing a rating scale from 1 (extremely dislike) to 5 (extremely liking). The attributes subjected to evaluation included appearance, texture, flavor, overall liking, and acceptance.

Table 2: Sensory attributes and their definitions of the extruded phyto-snacks

Sensory Attributes	Definition
Fracturability	Refers to the food's capacity to shatter or break into smaller pieces when bitten by incisors, reflecting its crispness and brittleness.
Hardness	Denotes the degree of resistance experienced when food is compressed by the molar teeth, indicating its firmness or resistance to deformation.
Chewiness	Quantify by the chews required for the food to be adequately masticated and ready for swallowing, offering insights into its texture and resilience during consumption.

2.4 Data analysis

Statistical analysis was conducted using the following methods; data for physical properties and sensory attributes were initially checked for outliers and normality using appropriate statistical tests and visualization tools. Pearson's correlation coefficient (r) was performed to quantify the strength and direction of linear relationships between pairs of variables. The significance level (p-value) was determined for each correlation coefficient. Correlation coefficients were interpreted as: $|r| < 0.3$: Weak correlation, $0.3 \leq |r| < 0.6$: Moderate correlation, and $|r| \geq 0.6$: Strong correlation. Scatter plots and correlation heatmaps were generated to visualize the relationships between physical properties and sensory attributes. The statistical analysis was conducted using SPSS, ensuring accuracy and reproducibility of results. The results of the correlation analysis were reported, including correlation coefficients, significance levels, and any notable findings.

The statistical analysis of the correlation between physical properties and sensory evaluation attributes provides valuable insights into the relationship between these variables, contributing to a deeper understanding of the factors influencing the sensory appeal of Extruded Phyto-snacks. These findings have practical implications for enhancing product quality and consumer satisfaction in the snack food industry.

3. Results

The results of this study, as presented in Table 3 and Table 4, offer valuable insights into the correlation between the physical properties and sensory evaluation of Extruded Phyto-Snacks.

3.1 Physical Properties:

In Table 3, the physical properties of the Extruded Phyto-Snacks were evaluated using Texture Profile Analysis (TPA). Fracturability, a measure of the snack's brittleness, was found to have an average value of 35.266±0.58 N, indicating its resistance to breakage. Hardness, which reflects the force required to compress the snack, had an average value of 52.611±0.73 N, suggesting a relatively firm texture. Chewiness, quantifying the degree of necessary mastication was determined to be 15.89±3.36. These physical property measurements provide a foundational understanding of the textural characteristics of the snack.

3.2 Sensory Evaluation:

A sensory panel consisting of 100 untrained assessors evaluated the Extruded Phyto-Snacks for various attributes as detailed in Table 3. Fracturability in sensory evaluation received an average rating of 4.58±0.87 indicate that the panel generally perceived the snacks as having a high level of brittleness. Hardness in sensory evaluation garnered an average rating of 4.21±0.98, suggesting that the sensory panel considered the snacks moderately hard. Chewiness in sensory evaluation had an average rating of 3.87±1.25 specify that the snacks were perceived as moderately chewy. Additionally, attributes such as appearance (4.30±1.06), overall tasting (4.15±0.61), overall liking (4.56±0.94), and overall acceptance (4.40±1.31) were assessed, giving an overall impression of the snack's sensory appeal.

3.3 Correlation Analysis:

Table 4 displays the correlation coefficients between the TPA data and sensory attributes of the Extruded Phyto-Snacks. Notably, fracturability in the TPA strongly correlated with fracturability in sensory evaluation ($r = 0.776$, $p < 0.05$). The correlation indicates that the instrumental measurement of brittleness aligns well with the sensory perception of this attribute. Similarly, hardness in the TPA showed moderate positive correlations with both fracturability ($r = 0.452$, $p < 0.05$) and chewiness ($r = 0.687$, $p < 0.05$) in sensory evaluation. This implies that the firmness of the snacks, as determined by instrumental measurements corresponded moderately well with the sensory assessment of both brittleness and chewiness. Chewiness in the TPA

demonstrated moderate positive correlations with fracturability ($r = 0.634$, $p < 0.05$) and hardness ($r = 0.769$, $p < 0.05$) in sensory evaluation. This suggests that the instrumental measure of chewiness aligns moderately with sensory perceptions of both brittleness and hardness.

The strong correlations between specific physical properties and sensory attributes highlight the importance of these factors in determining the sensory experience of Extruded Phyto-Snacks. Understanding these relationships is crucial for product developers as it allows for precise control and optimization of texture to meet consumer preferences. A balance between brittleness, hardness, and chewiness can be fine-tuned to create nutritionally valuable and sensory-appealing snacks. This research enhances extruded Phyto-Snacks, positioning them favorably in the competitive snack market, where texture plays a pivotal role in consumer acceptance.

Table 3: Physical properties and Sensory evaluation of extruded phyto-snack product

	Values
Texture Profile (n=10)	
Fracturability (N)	35.266±0.58
Hardness (N)	52.611±0.73
Chewiness	15.89±3.36
Sensory Evaluation (n= 100)	
Fracturability	4.58±0.87
Hardness	4.21±0.98
Chewiness	3.87±1.25
Appearance	4.30±1.06
Overall tasting	4.15±0.61
Overall liking	4.56±0.94
Overall acceptance	4.40±1.31

Table 4 Correlation values between TPA and sensory test of extruded snack product

Texture profile	**Sensory attributes**		
	Fracturability	**Hardness**	**Chewiness**
Fracturability (N)	0.776	0.213	0.125
Hardness (N)	0.452	0.687	0.662
Chewiness	0.634	0.769	0.641

Correlation using Pearson's coefficient $p<0.05$

4. Discussion

This study investigated the correlation between the physical properties and sensory evaluation of Extruded Phyto-Snacks. We utilized Texture Profile Analysis (TPA) and sensory assessment by a trained panel of 100 evaluators. Our

findings provide valuable insights into this innovative snack product's textural attributes and sensory appeal.

The physical properties of Extruded Phyto-Snacks, including Fracturability, Hardness, and Chewiness, were measured through TPA. These measurements revealed that the snacks exhibited high brittleness, moderate hardness, and chewiness. These characteristics form the foundation of the snack's textural profile [6].

Sensory evaluation results indicated that the assessors generally perceived the snacks as brittle, moderately hard, and chewy. Additionally, sensory attributes such as Appearance, Overall Tasting, Overall Liking, and Overall Acceptance provided a comprehensive understanding of the product's sensory appeal. The alignment between the sensory ratings and the physical measurements is paramount for product developers and quality control in the food industry [7].

The correlation analysis revealed significant associations between specific physical properties and sensory attributes. Notably, Fracturability, a measure of brittleness, exhibited a strong positive correlation with its sensory counterpart, indicating that instrumental measurements align well with sensory perceptions. Similarly, Hardness and Chewiness in TPA showed moderate positive correlations with sensory evaluations of these attributes, suggesting that instrumental measurements moderately correspond with sensory assessments [8].

These findings have practical implications for the development and optimization of Extruded Phyto-Snacks. Product developers can create snacks that align more closely with consumer preferences by fine-tuning the physical properties, such as brittleness, hardness, and chewiness. The physical properties are essential for maintaining and increasing the product's market appeal, particularly in the highly competitive snack industry.

5. Conclusion

In conclusion, this study highlights the significance of understanding the interplay between physical properties and sensory attributes in snack product development. The correlations identified herein offer a roadmap for improving the sensory appeal of extruded Phyto-Snacks, ensuring their continued success in the market while meeting the demands of health-conscious consumers. Future study in this domain may explore additional factors influencing sensory perception and refine the snack's textural attributes for enhanced consumer satisfaction.

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