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Effect of Freeze Drying on the Macronutrient characteristics of Chenna Balls

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ABSTRACT: Dairy products, including chhena, are essential constituents of a nutritious diet, enjoying widespread recognition globally, particularly within vegetarian culinary practices. The preservation of chhena poses a significant challenge, and the core focus of this research centers on the exclusive method for enhancing the chhena's shelf life. This investigation's principal aim was to scrutinize the impact of macronutrients, encompassing moisture content, protein, fat, carbohydrates, and ash content, on specimens derived from diverse milk fat formulations, encompassing 3%, 5%, and 7%. The moisture content in the freeze-dried chhena balls was found to range from 0.63% to 1.07% (w.b.), while protein levels varied between 17.03% and 17.77%. The fat, carbohydrate, and ash content in freeze-dried chhena balls exhibited a range of 2.77% to 6.93%, 73.29% to 78.18%, and 0.91% to 1.31%, respectively. These findings provide valuable insights into the nutritional composition of chhena and its variations based on milk fat compositions.

Keywords: Freeze Drying, Chhena, Moisture Content, Protein, Fat, Carbohydrate, Ash Content.

INTRODUCTION

Chhena, or Chhena, represents an Indian variant of soft cheese achieved through the heat-acid coagulation of milk. This dairy product is meticulously crafted by heating whole cow or buffalo milk or a blend of both, bringing it to a boil, and subsequently introducing lactic acid, citric acid, or an appropriate coagulating agent. The ensuing process involves the removal of whey (Sahu and Das 2009). Traditionally, the method for Chhena production entails heating milk to its boiling point in an open pan and then allowing it to cool within the temperature range of 75 to 80°C while continuously stirring. Following this, a 1 to 2% quantity of acid coagulant is incorporated. During coagulation, the milk-acid mixture is gently stirred with a ladle, continuing until the milk precipitates and settles at the base of the container. The clear whey residing on the surface is then filtered through a muslin cloth, and the resulting semi-solid curd is collected for consumption. Chhena, recognized for its high fat and protein content, along with significant levels of fat-soluble vitamins A and D, and low sugar content, emerges as a highly recommended dietary choice for individuals managing diabetes (De, 1980).

It has been documented that several factors, including the type of milk used, the heat treatment applied to the milk before acidification, the coagulation temperature, the acidity of the milk-acid mixture, and the duration for which the chhena-whey mixture is allowed to reside prior to the separation of milk solids from whey, can exert an influence on both the yield and chemical composition of Chhena. On the other hand, compositional elements such as calcium content, fat levels, the presence of colostrum, and the potential adulteration of milk with water or starch have the capacity to impact the texture of Chhena (Jonkman and Das 1993).

Furthermore, Chhena derived from cow and buffalo milk exhibited favorable flavor profiles, whereas Chhena prepared from goat's milk displayed a slightly acidic taste. Additionally, Chhena sourced from cow's milk demonstrated higher moisture, protein, and ash contents, albeit lower fat and lactose contents when compared to Chhena originating from buffalo milk (Sahu, 2007).

Research has revealed that the production of high-quality Chhena from buffalo milk can be achieved through the utilization of modified processing parameters. For instance, Chhena blended with cream has been observed to possess amildlyd acidic flavor, a soft body, and a smooth texture, rendering it suitable for the production of spreads, particularly those with desirable spreadability at refrigeration temperatures and high nutritional value, achieved through the incorporation of functional ingredients (Chappalwar *et al.,* 2010).

Since chhena is one of the base materials for production of a variety of milk products like Paneer, Rasgolla (a type of sweet), Sandesh and Gulab jaman in Asian countries, has not been well studied in the (remove this word Province) of Sindh or even in Pakistan; thus an approach was hypothesized to produce and evaluate the quality and yield of chhena by using two different milk sources (milk of cow & buffalo) (Jindal and Grandison 2001).

Chhena exhibits a notably short shelf life, underscoring the critical importance of extending its durability (Chitranayak *et al.*, 2017). While freeze drying remains a relatively expensive method, its economic viability hinges on the demand for unique product advantages, including ease of handling, superior culinary quality, reduced weight, decreased bulk, and the capacity for ambient temperature storage. These advantages are considered substantial enough to warrant the associated additional costs. If this process could yield a reasonably high-quality product upon rehydration, it could potentially make the application of freeze drying to chhena balls a feasible option. Furthermore, this could open doors to capturing a share of the export market upon reconstitution (Sulieman *et al.*, 2018).

MATERIAL AND METHODS

The technique of freeze drying, a pioneering method of dehydration, originated in the mid-1940s. It was prompted by the necessity to establish a means for the long-term storage of blood at room temperature during World War II. The research endeavors in this field were undertaken in various laboratories within the Department of Post-Harvest Process and Food Engineering at the College of Agricultural Engineering, JNKVV, Jabalpur, Madhya Pradesh.

Raw materials used for the final preparation of dehydrated product. The nature and quantity of ingredients wield a substantial influence over product texture, consistency, nutritional value, economic feasibility, and the likelihood of acceptance of the dehydrated product. Initially, raw milk with varying fat compositions was sourced from the market, and adjustments were made to standardize its fat content. This standardized milk served as the primary raw material for the production of freeze-dried chhena balls. It's important to note that all chemicals employed in this study were of analytical grade.

Experimental protocols were established to investigate the drying kinetics of chhena balls, incorporating measurement intervals of 45 minutes to assess sample moisture content. The experimental parameters followed conventional freeze-drying variables as described by Menlik *et al.* (2010), which encompassed primary drying temperatures, sample load, sample thickness, and milk composition.

Plan of Work

Sr. No.	Independent variables	Range		
1.	Loading capacity (g)	100	200	300
2.	Sample diameter (cm)	1	2	3
3.	Primary drying temperature (°C)	-25	-20	-15
4.	Milk fat composition (%)	3	5	7

The samples were used to determine the quality based on several parameters viz. physicochemical properties like moisture content, fat content, protein content, carbohydrate content, and ash content of freeze-dried chhena balls.

Analytical Methods

Sampling. In the case of sampling fresh chhena, the procedure outlined in ICAR Bulletin No.70 (1951) for channa sampling was adhered to. To sample freeze-dried chhena balls, they were processed into a fine powder using a mixer (specifically, a Preethi Zodiac MG-218 Mixer grinder), and this powder was subsequently employed for further analysis.

Moisture Content. The moisture content in the chosen sample was determined using the AOAC (Association of Official Agricultural Chemists) method from 1984. A 5-gram sample was placed inside a pre-weighed moisture box. This sample was then subjected to drying for a duration of 24 hours at a temperature of 105°C in a hot air oven. Afterward, the sample was allowed to cool in a desiccator, and its weight was measured again. The variance in weight of the moisture box before and after drying provided the moisture content of the sample.

Calculation

$$\text{Moisture content (w.b.) \%} = \frac{(W_1 - W_2)}{W_1} \; 100$$

where,

W_1 = Weight in gram of the dish with the material before drying.

W_2 = Weight in gram of the dish with the material after drying.

Crude Fat Content. The determination of the fat content in the sample was carried out following the procedure outlined in AOAC (Association of Official Agricultural Chemists) from 1984. A 5-gram sample was accurately weighed and placed into a thimble, which was then sealed with cotton. The estimation of fat content involved the extraction of the sample using petroleum ether solvent (AR grade, 60-80°C) over an 8-hour period using Soxhlet's extraction method. Subsequently, any excess solvent was distilled off, and the remaining solvent was eliminated by heating at 80ºC in an oven for 4-6 hours. The flask was then weighed (marked as B), and the fat content was determined through the following calculation:

Calculation:

$$\text{Crude fat (\%)} = \frac{\text{Weight of flask (B)} - \text{Weight of flask (A)}}{\text{Weight of sample}} \, 100$$

Crude Protein Content. The protein content in the sample was determined using the conventional micro-Kjeldahl digestion and distillation procedure as outlined in AOAC (Association of Official Agricultural Chemists) from 1984.

Reagents:

1. Catalyst mixture - A mixture of 100g K_2SO_4, 20g of $CuSO_4$ and 2.5 g of SiO_2.
2. Sodium hydroxide solution: 40% (w/v).
3. Boric acid solution: 2% (w/v).
4. Concentrated sulphuric acid AR (sp. gr. 1.81).

5. Mixed indicator: 2 parts of 0.2% (w/v) methyl red and 1 parts 0.2% (w/v) methyl blue in absolute alcohol.
6. Standard sulphuric acid (0.1N).

Calculation:

$$\text{Nitrogen (\%)} = \frac{\text{Normality of } H_2SO_4 \times \text{Volume of } 0.1\,N\, H_2SO_4 \times 14}{\text{Weight of sample} \times 100}\ 100$$

Crude Protein (%) = Nitrogen (%) × 6.25

Ash content

The ash content in the sample was estimated by the procedure indicated in the AOAC (1984).

Calculation:

$$\text{Ash (\%)} = \frac{\text{(Initial weight of empty crucible and sample)} - \text{(Final weight of crucible with ash)}}{\text{Weight of sample}}\ 100$$

RESULTS AND DISCUSSION

A total of 29 experiments were conducted using a Box-Behnken design. These experiments aimed to assess various factors, including moisture content, protein content, fat content, carbohydrate content, and ash content, in the freeze-dried chhena balls.Chhena was prepared by the method described by Sahu and Das (2009).

Biochemical properties of freeze-dried chhena balls

Moisture Content. The final moisture content of the freeze-dried chhena balls exhibited a narrow range, with the lowest value of 0.63% achieved at a primary drying temperature (PDT) of -20°C, with a 5% milk composition, 1 cm chhena ball diameter, and a 100 g sample load. In contrast, the highest moisture content value of 1.07% was observed at -15°C PDT, with a 5% milk composition, 300 g sample load, and 2 cm chhena ball size. The probability value of the quadratic model indicates that the machine parameters, namely sample load, primary drying temperature, and chhena ball diameter, had a positively linear and significant effect on moisture content, with a confidence level of 1%.

The mathematical model includes regression coefficients and standard errors, providing information about the significance and relevance of each term. A positive coefficient at the linear level implies that as the selected parameters increased, the response also increased, and vice versa. On the other hand, negative quadratic terms suggest that the response reaches its maximum value (1.07) at the center point, while positive quadratic terms indicate that the response achieves its smallest value (0.63) at the center point. This understanding helps in identifying the optimal conditions for the freeze-drying process of chhena balls.

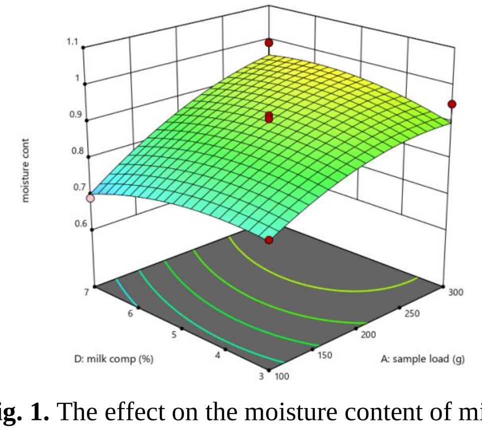

Fig. 1. The effect on the moisture content of milk composition and sample load of chhena balls.

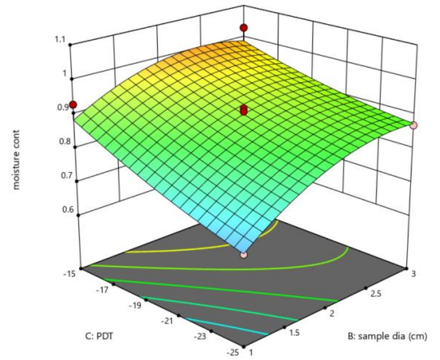

Fig. 2. The effect on the moisture content of primary drying temperature and sample load of chhena balls.

Protein Content. The protein content of the chhena balls was notably influenced by the freeze-drying process conditions. The highest value of crude protein content, reaching 17.77%, was attained when using a primary drying temperature (PDT) of -15°C, a 5% milk composition, 2 cm chhena ball diameter, and a 200 g sample load. Conversely, the lowest protein content, which was 17.03%, was observed at -20°C PDT, with a 7% milk composition, a 300 g sample load, and chhena balls of the same size. This demonstrates the significance of these conditions in determining the protein content of the freeze-dried chhena balls.

The results indicate a significant effect ($p<0.01$) of the sample load and primary drying temperature on the crude protein content of the chhena balls. Additionally, it was observed that milk composition had a significant ($p<0.05$) inverse relationship with protein content. The second-order model derived from the experimental data revealed that sample load and primary drying temperature significantly influenced the non-linearity in the data, underscoring the importance of these parameters in the process optimization for freeze-drying chhena balls.

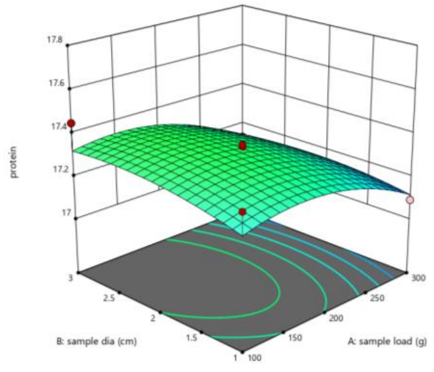

Fig. 3. The effect on protein content of sample diameter and sample load of chhena balls.

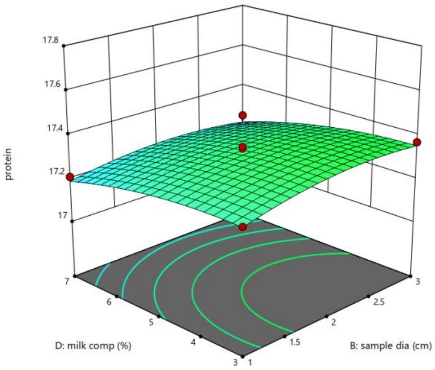

Fig. 4. The effect on protein content of milk composition and sample diameter of chhena balls.

Fat Content. The crude fat content of freeze-dried chhena balls, which ranged from 2.77% to 6.93%. These variations were substantially influenced by the machine parameters used in the experiments.

The mathematical model includes regression coefficients and standard errors, providing information about the significance and relevance of each term. A positive coefficient at the linear level indicates that when the selected parameters were increased, the response also increased, and conversely, decreased when the parameters were decreased. Negative quadratic terms suggest that the response reaches its maximum value (6.93%) at the center point, while positive quadratic terms indicate that the response achieves its smallest value (2.77%) at the center point. This insight helps in identifying the optimal conditions for the freeze-drying process of chhena balls with respect to crude fat content.

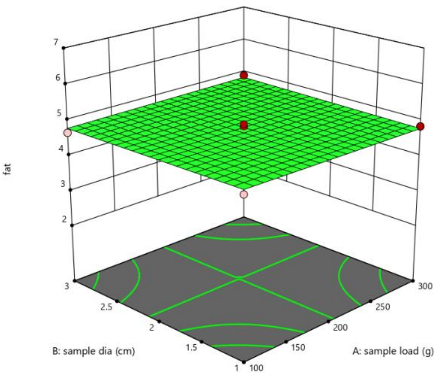

Fig. 5. The effect on fat content of sample diameter and sample load of chhena balls.

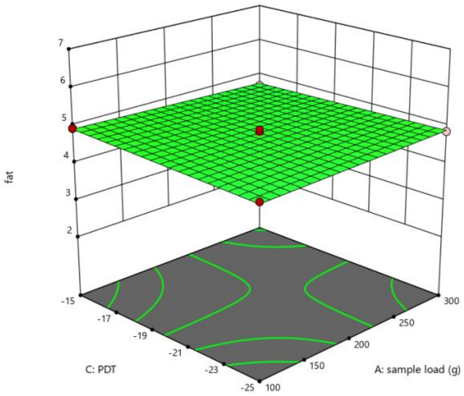

Fig. 6. The effect on fat content of primary drying temperature and sample load of chhena balls.

Carbohydrate Content. The carbohydrate content of freeze-dried chhena balls displayed a range of values, from 73.29% to 78.18%. Machine parameters played a significant role in influencing carbohydrate content. Specifically, the diameter, primary drying temperature, and milk composition had a negative linear impact on freeze-drying chhena balls at a confidence level of 1%. At the quadratic level, the effects of sample load, diameter, and primary drying temperature were found to be significant (p<0.01). Additionally, the interaction between sample load and primary drying time was significant at a 5% confidence level, while all other interactions were found to be non-significant.

The mathematical model includes regression coefficients and standard errors, providing information about the significance and relevance of each term. A positive coefficient at the linear level indicates that when the selected parameters were increased, the response also increased, and vice versa. Negative quadratic terms suggest that the response reaches its maximum value (78.18%) at the center point, while positive quadratic terms indicate that the response achieves its smallest value (73.29%) at the center point. This understanding assists in identifying the optimal conditions for freeze-drying chhena balls with respect to carbohydrate content.

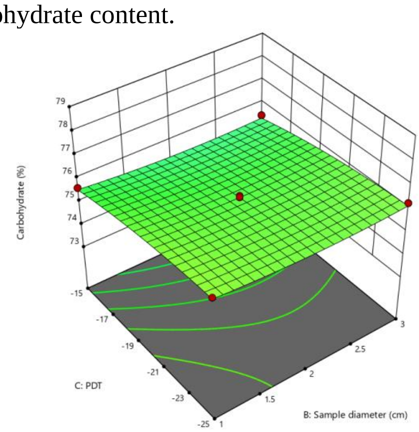

Fig. 7. The effect on the carbohydrate of primary drying temperature and sample diameter of the chhena balls.

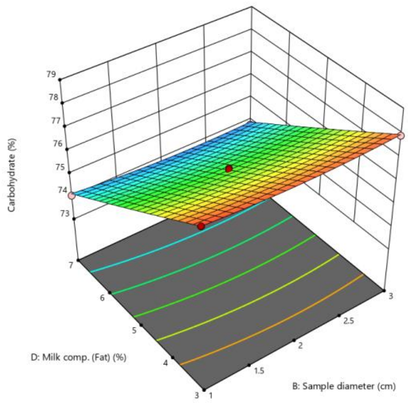

Fig. 8. The effect on the carbohydrate content of milk composition and sample diameter of chhena balls.

Ash Content. In the experiments conducted, the ash content of freeze-dried chhena balls varied, with the highest value of 1.31%, and the lowest value of 0.91%. Mechanical parameters had a relatively minimal effect on the total ash content. Among all the models, only the primary drying temperature and milk composition at the linear level were found to be significant (p<0.01), while the remaining parameters were non-significant.

The mathematical model comprises regression coefficients and standard errors, offering insights into the significance and relevance of each term. A positive coefficient at the linear level signifies that when the selected parameters were increased, the response also increased, and conversely, decreased when the parameters were decreased. Negative quadratic terms suggest that the response reaches its maximum value (1.31%) at the center point, while positive quadratic terms indicate that the response achieves its smallest value (0.91%) at the center point. This information aids in identifying the optimal conditions for freeze-drying chhena balls in terms of ash content.

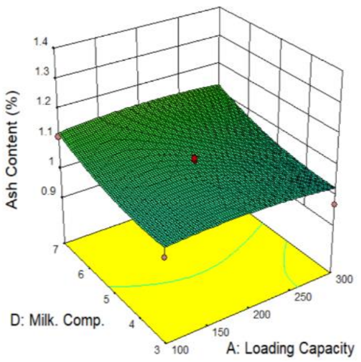

Fig. 9. The effect on ash content of sample load and milk composition of the chhena balls.

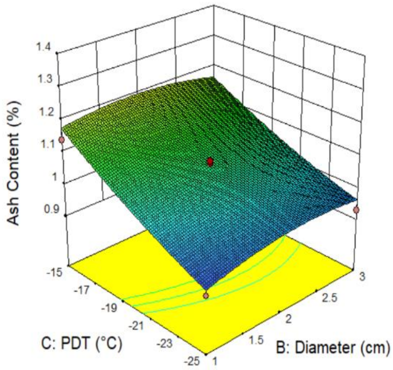

Fig. 10. The effect on ash content of primary drying temp. and diameter of the chhena balls.

CONCLUSIONS

It is concluded that the optimization of the chhena ball production process and its effects on quality attributes, particularly in relation to varying diameters and processing conditions. The results of this study have the potential to impact the food processing industry positively, as they shed light on the potential for improving the production and quality control of chhena balls. These findings also have implications for enhancing the shelf-life and overall quality of dairy products, benefiting both producers and consumers alike. Future research may delve into the practical applications and advancements in chhena ball production processes and their relevance to the broader food industry.

FUTURE SCOPE

We propose the utilization of freeze-drying, accompanied by a regulated heating rate and freeze microscopy examination.

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Conflict of Interest. None.

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