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Optimization of Process Parameters for the Development of Ready-To-Eat (RTE) Intermediate Moisture Chicken Bar

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Abstract: In the study, an intermediate moisture food bar was developed using dried chicken shreds as the primary protein source. The base matrix was formulated with appropriate ingredients and binders, while the shredded chicken was processed using hot air drying for various time intervals. Drying time of 3 hours was found to be optimal for the chicken bar preparation based on the texture and sensory characteristics. Compression technology was successfully employed to compact the bar, reducing bulk and making it more convenient to handle. Lecithin was incorporated to prevent stickiness during the compression process. The final bar, made with an equal proportion of dried shredded chicken and base matrix, along with date syrup, was found to be acceptable in terms of texture and sensory parameters. The bars were vacuum packed in metalized polyester pouches. Texture analysis revealed the bar's soft, easily biteable nature, with a firmness value of 21.05 N. Additionally, the bar met microbiological safety standards and complied with FSSAI regulations. With a protein content of 33.25%, this chicken bar offers a great nutritional boost for highly active individuals such as athletes and military personnel, as well as busy civilians who need a quick, convenient source of protein. The developed bar is portable and convenient with the nutritional benefits of chicken protein.

Keywords: Chicken, protein bar, base matrix, hot air drying, compression.

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1. Introduction

With increasingly demanding work schedules, consumers are seeking quick and convenient meal options (Lee and Lin, 2013). These ready-to-eat and easy-to-prepare foods cater to the need for time-efficient solutions for both individuals and families. They offer several advantages, such as ease of preparation, portability, long shelf life, and a combination of these convenient traits. Modern consumers often prioritize healthy eating, making it essential for convenience foods to offer healthy choices, whether through portion sizes, organic ingredients, or functional benefits (Shantanu, 2021).

Food bars have occupied a significant place in the convenience food market (Arshad, 2019). These energy-dense, ready-to-eat nutritional snacks are ideal for consumption on the go (Aakash and Gaga, 2020; Craig and Jacqueline, 2013). While a wide variety of vegetarian options are available, non-vegetarian bars are less common. Poultry meat is gaining a high market potential and it is widely consumed world-wide (Barbut, 2020). Poultry meat, especially chicken, is highly nutritious, lean, and rich in protein, containing all essential amino acids, vitamins such as A and E, thiamine, and niacin (Michel, 2011). Additionally, its distinctive flavor and low cost make it an attractive option for inclusion in bars. It has soft muscle fibers which are liked by different age group people (Shai and Leishman, 2022). It is a healthier choice compared to red meat due to its lower fat and cholesterol content. Taste and texture play crucial roles in consumer acceptance, with preferences varying widely across different demographics. To achieve taste and texture intermediate moisture foods are ideal for chicken bar preparation. Intermediate moisture food is designed to have a longer shelf life compared to wet or perishable food, while still maintaining a soft and palatable texture (Voorhies *et al*., 2019). With a moisture content typically ranging from 15% to 45%, these foods strike an optimal balance that controls microbial growth and inhibits bacteria, yeast, and mold (Aiswarya *et al*., 2023). The advantages of intermediate moisture foods include their extended shelf life, reduced weight and volume compared to wet foods, and the ability to maintain a desirable texture and flavor (Voorhies *et al*., 2019). Additionally, they provide a variety of options, such as snacks, confectioneries, and other semi-moist items. Compression technology is a preferred method to prepare intermediate moisture dehydrated food bars suitable for direct consumption. For the preparation of chicken bar, the form of chicken meat used, drying time, temperature and applied pressure plays an important role during processing. This is necessary for establishing proper sensory and textural properties. These properties have to be in accordance with the ingredients and binders which are

used in the preparation of the bars. The limitations in obtaining a good chicken bar lie in its color, flavor and texture as it is prepared in combination of several ingredients. These ingredients can deliver macro and micro nutrients and also functionality. By using suitable binders these can be turned into a bar with acceptable flavor, texture and decent appearance (Jayathilakan *et al*., 2017).

The aim of this study is to develop a RTE, intermediate moisture protein-rich chicken bar with a mouth feel of chicken. The bar is rich in protein and is designed to enhance physical strength and energy. Protein plays a vital role in muscle development and endurance, making it especially beneficial for athletes, soldiers, working professionals, and children experiencing protein malnutrition.

2. Materials and Methods

2.1. Raw Materials

The chicken meat used in this study was procured from Mysuru local market. Boneless and skinless meat within 1-2 hours (h) of slaughter and after rigor mortis was cut into uniform pieces. The meat was washed thoroughly using tap water and RO water and used in the study. The other ingredients like corn flour, milk powder, sugar, date syrup, soy lecithin, chilli powder, turmeric powder, salt, ginger garlic paste, lemon, curd etc were also procured from Mysuru local market.

2.2. Chemicals and Reagents

Analar grade chemicals and reagents employed in the study were procured from M/s Merck, Hi-media and SRL brand.

2.3. Preparation of Dehydrated Chicken

A process for the preparation of dehydrated chicken was standardized at the laboratory. The washed chicken pieces were marinated with curd, ginger garlic paste, salt and other spices for an hour at 4 °C. Marinated chicken was cooked for 15 minutes in a pressure cooker. After cooking chicken was allowed to cool at RT and it was shredded manually. The chicken shreds were coated with butter to avoid case hardening during drying. The chicken shreds were hot air dried at 60 °C temperature at different intervals of time i.e. 3, 4 and 5 hours respectively.

2.4. Preparation of Base Matrix

Base matrix was prepared using corn flour, tomato powder, milk powder, salt, icing sugar, cumin powder, pepper powder, chilli powder, chicken masala,

spice mix and soy lecithin. All the above mentioned ingredients were mixed thoroughly. Corn flour was subjected to microwave drying for 3 min, milk powder for 2 minutes and other spices for 1 minute (min) to reduce the microbial load before mixing the ingredients to form base matrix. The moisture content of the base matrix was 6.27 % and water activity was 0.298.

2.5. Preparation of Chicken Bar

The chicken bars were optimized by varying the ratio of dehydrated chicken and base matrix as 2:3, 1:1 and 3:2 and binder levels from 4.5 to 6.5%. Chicken bars were prepared using 3 hours, 4 hours and 5 hours dehydrated chicken and mixed with base matrix in the preparation mentioned above. Bars of 25 g and 10 g were prepared using Carvar press compression machine from Germany. Different moulds were used to prepare the bars. The bars were vacuum packed in metalized polyester pouches which has good barrier properties and stored at room temperature for further study.

2.6. Sensory Analysis

The bars were subjected for sensory analysis by 13 semi trained panelists using 9 point hedonic scale (9-like extremely, 1-dislike extremely) as per Murray *et al*., 2001. The overall acceptability of the product is estimated from these studies.

2.7. Proximate Analysis

Proximate analysis of the optimized chicken bar was carried out as per AOAC 2000 for moisture, protein, fat, total ash and carbohydrates.

2.8. Determination of Water Activity

Water activity (a_w) was determined using Labmaster a_w (Novasina instrument, Switzerland) and Novalog software at RT.

2.9. Determination of Colour

Colour values (L^*, a^*, b^*) were determined using a colorimeter ColorQuest XE (Hunter Lab, Reston, USA) using D65 illuminant and observation angle of 10 in terms of CIELAB parameters L^* (lightness, 0=black, 100=white), a^* (redness and greenness) and b^* (yellowness and blueness).

2.10. Determination of pH

pH measurements were taken in a Lab-scan pH meter (Eutech Instruments, Singapore). Five gram sample was homogenized thoroughly after grinding and

mixed with 10 ml of double distilled water and kept for 15 min. The samples were then mixed thoroughly once again and filtered through Whatman No.41 filter paper. The filtrate was then analysed in the pre-calibrated pH meter by dipping the electrode in the filtrate. pH along with the temperature of samples was then noted.

2.11. Texture Analysis

Texture analysis of the sample was carried out using TA Plus, Texture Analyzer (Lloyd Instruments, Hampshire, UK). The analysis technique used was Snap Strength Set-up (40/0615) with a three-point bending jig to obtain firmness (N) analyzed using Nexygen software. Other test parameters fixed were; pre and post-test speed of 45 mm/min, clearance 2-3 mm, trigger force of 10 gf, and depression limit of 8 mm. Results and findings were then interpreted according to (Bourne, 1978).

2.12. Microbial Analysis

Microbiological analysis (TPC, Coliforms and Yeast & Molds) was carried out according to the FSSAI Manual on Methods of Analysis, 2024. The predominant pathogens associated with meat such as *E. coli, Staph. aureus, Salmonella, Listeria* were also determined using the above manual.

2.13. Statistical Analysis

All experiments were repeated three times and data sets were subjected to analysis of variance (ANOVA) using the general linear models. Significant differences between the sample means were determined at $p<0.05$ levels by ANOVA.

3. Results and Discussion

Ingredients of chicken bar were standardized by combining dehydrated chicken and base matrix in definite proportions with incorporation of binders and anti sticking agents. For the preparation of the bar, chicken was used in the form of shreds.

3.1. Optimization of Moisture Content of Chicken Shreds

Cooked and shredded chicken meat was dried at 60°C in a hot air oven for various time intervals i.e. 3-5 h and analysed for moisture content (%) and water activity (a_w). The moisture and water activity of the hot air dried chicken are shown in Table 1.

Table 1: Moisture content (%) and water activity (a_w) of fresh and dehydrated chicken meat

Chicken samples	*Moisture content (%)*	*Water activity (a_w)*
Raw chicken	77.19	0.980
0 h dried cooked chicken shreds	68.90	0.880
3 h dried cooked chicken shreds	46.61	0.835
4 h dried cooked chicken shreds	35.14	0.782
5 h dried cooked chicken shreds	13.53	0.526

The results indicate that moisture content and water activity values were found to be higher in the raw chicken than cooked chicken. The moisture content of cooked chicken meat was 68.90 % which was gradually reduced while drying. Heat breaks down the cellular structure and causes water to escape from the muscle fibres during cooking. Also, denaturation of proteins during cooking leads to a reduction in the ability of the meat to hold water. Similar findings were reported in the study by (Ozcan and Bozkurt, 2015) on the physical and chemical properties of meat using different cooking methods. (Hii, 2014) in their study on convective air drying of raw and cooked chicken meat observed that cooked chicken samples had lower moisture content and dried faster than the raw samples. The lower moisture content in cooked meat was due to decrease in moisture holding capacity and shrinkage that expelled the inner moisture of the meat to the surface during cooking. The moisture content reduced from 68.90 % to 13.53 % at the end of 5 h of drying. The initial water activity (a_w) of cooked chicken meat was 0.880 which got reduced to 0.526 during drying at the end of 5 hours (h). The values showed that the cooked chicken sample is perishable with higher water activity value than the dried samples.

3.2. Preparation of Base Matrix

The base matrix was prepared using several ingredients and was analysed for its moisture content and water activity. The moisture content of the base matrix was 6.29 % and water activity (a_w) was 0.298. The reason for low water activity of base matrix might be due to the dry powders which were used in the preparation of base matrix. Ingredients such as corn flour, tomato powder, milk powder, salt, chilli powder etc. were used in the preparation of base matrix. The data shows that the base matrix contained low moisture and hence water activity was also lower. For most foods, the critical point of water activity is in between 0.6–0.7, below which no microorganisms can grow (Pittia, 2015).

3.3. Preparation of Chicken Bar

Chicken bar was prepared by combining base matrix and dehydrated chicken shreds in various proportions. Chicken shreds dried for different intervals of time like 3 h, 4 h and 5 h were used in the preparation of bars with base matrix and binder. Prepared chicken bars were subjected to sensory and physico-chemical analysis. The sensory data is shown in Table II based on a 9 point hedonic scale. Hedonic scale method was used to determine the level of acceptance for chicken bar and to compare results (Stone and Sidel, 1993). Changes in moisture content and water activity values are shown in Table 3.

The level of acceptance for chicken bar was assessed using the hedonic scale method. The factors like color, texture, odor, taste, and overall acceptability were evaluated on a 9 point hedonic scale by a panel of judges, keeping 9 for excellent and 1 for very poor as per Murray *et al*. (2001). The sensory characteristics of the developed products were evaluated.

The results showed that the chicken bar prepared with chicken shreds dried for 3 hours and a base matrix in a 1:1 ratio (3A2) received higher sensory scores, as it was easy to break, chew, and had a desirable texture. The chicken bar prepared with 4 hours and 5 hours dehydrated chicken shreds was less liked by the panelist, as the drying time of chicken led to hardness of chicken shreds in turn making the bar hard to chew. Also, the composition 3:2 ratio of base matrix and dried chicken shreds was not liked by the panel members, due to less chicken content.(Table 2)

Table 2: Sensory evaluation of chicken bar

*Chicken bar**	*Color*	*Texture*	*Odor*	***Taste***	***OAA***
3A1	7.4 ±0.69	6.5 ±0.88	7.0 ±1.22	6.1 ±1.05	6.5 ±0.88
3A2	**7.1 ±0.61**	**6.6 ±1.1**	**7.1 ±0.61**	**6.7 ±0.83**	**7.07 ±0.95**
3A3	6.3 ±1	5.6 ±1.0	8.3 ±0.20	7.5±0.65	7.03±1.15
4A1	6.8 ±0.60	6.2 ±0.97	6.8 ±0.60	5.9 ±0.39	6.45 ±0.76
4A2	7.1 ±0.61	6.3±1	7.0±1.22	6.7±0.83	6.78±0.83
4A3	6.8 ±0.60	5.5±1.01	6.9±0.83	5.8±0.33	6.46±0.75
5A1	6.3±1	5.7±0.97	6.8 ±0.60	5.7±0.97	6.1 ±1.05
5A2	7.1 ±0.61	6.0±1.11	6.8 ±0.60	5.8±0.33	6.3 ±1
5A3	6.0±1.11	5.2±0.44	6.7±0.83	5.9 ±0.39	6.02±1.08

*3,4,5 represent drying time of chicken shreds in hours, A1, A2, A3 represents different compositions of base matrix and chicken shreds which were used in the preparation of chicken bar i.e 3:2, 1:1 and 2:3

Moisture content and water activity values of chicken bar are reported in Table 3. The results showed that the moisture content in the chicken bar prepared using 3h dehydrated chicken varied from 23.81 % to 32.01 %. The moisture content in the chicken bar prepared using 4h and 5h dehydrated chicken varied from 17.25 % to 22 % and 10.31 % to 9.51 % respectively. The difference in the moisture content was due to the variation in the base matrix and dehydrated chicken ratios which were taken during the preparation of the bar and also the dehydration time of the cooked chicken shreds.

Table 3: Moisture content and water activity of chicken bar

*Chicken bar**	*Moisture content (%)*	*Water activity(a_w)*
3A1	23.81	0.778
3A2	**27.99**	**0.746**
3A3	32.01	0.725
4A1	17.25	0.635
4A2	18.31	0.678
4A3	22.00	0.715
5A1	10.31	0.426
5A2	10.61	0.431
5A3	9.51	0.429

*3,4,5 represent drying time of chicken shreds in hours, A1 A2 A3 represents different compositions of base matrix and chicken shreds which were used in the preparation of chicken bars i.e 3:2, 1:1 and 2:3

The water activity (a_w) of the chicken bar was also estimated and was observed that water activity was higher in the bar which was prepared using 3 h dehydrated chicken and varied from 0.778 to 0.725. The water activity in the bars which were prepared using 4 h and 5 h dehydrated chicken varied from 0.635 to 0.715 and 0.426 to 0.429 respectively. In general, high water activity foods are characterized by a moist, juicy, and tender texture. A decrease in water activity leads to hard, dry, and tough matrices. The effect of a_w on texture is generally associated with structural and physical changes due to moisture gain that may be related to a transition from a glassy to rubbery state (Roos, 1993). The difference in the water activity was due to the variation in the base matrix and dehydrated chicken ratios which were taken during the preparation of the bar and also the dehydrated time of the chicken shreds. The high a_w of 3A2 sample is due to the high a_w of 3 hours dried chicken shreds.

3.4. Colour analysis of Chicken Bar

Colour is an important factor affecting the food choices of consumers (Bayarri, 2001). Colour of chicken bar samples was measured according to Hunter L, a,

b colour scale, where L is a measure of lightness (0: black, 100: white), +a/-a is a measure of redness/greenness, and +b/−b is yellowness/blueness. Hunter L*, a * and b* values of chicken bar prepared using 3 , 4 and 5 h dried chicken shreds with equal amount of base matrix are shown in Table 4. Analysis revealed a significant difference in the colour parameters for all chicken bars. The L* value of chicken bar prepared using 3 h dried chicken shreds was 45.58 which gradually decreased to 42.58 and 33.54 and in 4 h and 5 h dried chicken shreds. This showed that as the drying time of the chicken shreds lead to the decrease in the lightness of the bar while redness increased from 18.65 to 20.97 and 30.40 respectively. This might be due to loss of moisture during drying (Gerald, 1987). There was no significant difference in the yellowness or b* values in all the three types of chicken bar. Based on the sensory evaluation and considering the moisture content and water activity, it has been observed that chicken bars containing 1:1 ratio of the 3 hours dehydrated chicken shreds and base matrix is the best product for consumption. Hence comparative evaluation of colour parameters (L* a* and b* values) was attempted to understand the effect of drying conditions on the colour of the bar developed.(Table 4)

Table 4: Colour analysis (Hunter L*, a * and b* values) of chicken bar

Chicken bar	*L**	*a**	*b**
3A2	45.58±0.89	18.65±0.03	26.26±1.16
4A2	42.58±1.74	20.97±0.65	25.55±3.70
5A2	33.54±0.27	30.40±1.69	25.61±4.23

A2= 45.5 base matrix, 50% dehydrated chicken, 4.5% binder

3.5. Texture analysis of Chicken Bar

The impact of drying time of shredded chicken on the overall firmness characteristics of the prepared chicken bar was studied using a snap strength setup. The studies revealed a proportional relationship between drying time and firmness of the product. However, chicken bar prepared using 3 hours (h) dried chicken shreds (3A2) and 4 hours (h) dried chicken shreds (4A2) showed a soft texture with firmness values (single hardness) of 21.05 N and 43.6 N respectively. The textural graph supported the above finding, i.e. moist texture with a more or less flat curve without any dip (Fig. 1). Whereas, the chicken bar prepared with shredded dried for 5 hours (h) (5A2) ended up in a harder texture 162.16 N, providing a crunchy feel to the product. The graph showed a sudden dip in the curve, showing the complete disintegration of the product and thereby supporting the findings. The total textural attributes of the product

can directly be correlated to the moisture content and water activity of the product (evident from subjective and objective assessment). The effect of water activity on texture is generally associated with structural and physical changes due to moisture gain that may be related to a transition from a glassy to rubbery state (Roos, 1993). Samples 3A2 and 4A2 showed moisture content of 27.99% and 18.31% respectively. Sample 5A2 reported a moisture content of 10.61%.

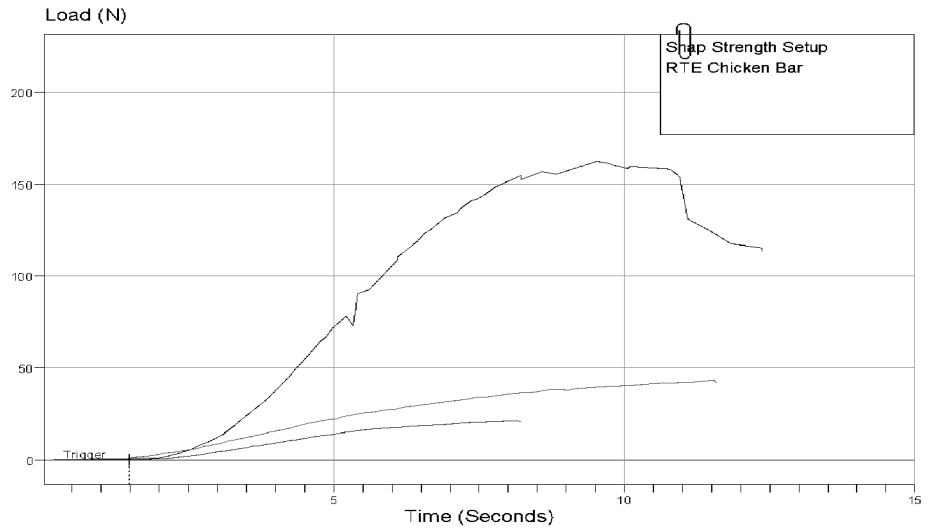

Figure 1: Texture analysis (Single hardness N) of chicken bar

3.6. Proximate Analysis of chicken bar

The bar had a protein content of 30.19 %, moisture 27.99 %, ash 5.4 %, fat 2.7 %, and carbohydrate 33.72 %. According to WHO, Recommended Dietary Allowance (RDA) of protein for an average adult is 0.8 g/kg body weight (b.w.). For endurance performance protein requirement for athletes is about 1.2-1.4 g/kg b.w. Military recommendation for dietary protein is 0.8 g/kg b.w. during low activity level and 1.5-2 g/kg b.w. during training. For an adult weighing 60 kg, the protein requirement is 48 g for normal activities, 72-84 g for athletes, and 90-120 g during military training. The developed chicken bar meets 62.5% of the Recommended Dietary Allowance (RDA) for an individual with average body weight of 60 kg.

3.7. Microbial Analysis of Chicken bar

The product was analyzed for initial Total Plate Count (TPC), Yeast & mold and coliform count. TPC for the chicken bar was 1.6×10^3 cfu/g (colony forming

unit), with no coliforms, yeasts & mold, or pathogens detected, which falls within the acceptable range as per FSSAI standards.

4. Conclusion

A chicken-based protein-rich, ready-to-eat, intermediate moisture (IM), compressed food bar has been developed which augments the protein requirement for physical strength and energy. The bar contains 30% protein from chicken shreds as the main protein source and other food ingredients for nutrition and texture. The developed bars were packaged using vacuum sealing in metalized polyester pouches. The bar represents a significant innovation within the convenient food category, offering a high-protein alternative to conventional snacks.

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