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Research Note

Optimization of Microwave Process Conditions for Squid Jerky Using Response Surface Methodology

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Abstract

This study successfully optimized the microwave processing conditions—namely microwave power, temperature, and drying time—for producing high-quality squid jerky with desirable moisture content and overall sensory acceptability. A 2^3 factorial experimental design was formulated, and a first order response regression model with interaction was developed for identifying the optimum microwave process condition with respect to moisture content and sensory attributes. The optimum microwave processing condition was found to be 530W at 60ºC with 50 minutes of drying time. Following process optimization, the nutritional profiling and quality evaluation of squid jerky was done with respect to biochemical and microbiological parameters. The histamine content of the squid jerky was found to be within acceptable limits, ensuring food safety. The findings highlight that the optimized microwave process not only improved the nutritional profile but also enhanced the overall quality of the squid jerky, making it a viable method for producing a shelf-stable product.

Keywords: Microwave, drying, squid, jerky, RSM

Jerky is a protein-rich, dried, and ready-to-eat shelf-stable meat product. Traditionally, it is prepared from sliced whole muscle or ground beef mixed with spices and is known for its chewy texture (Nummer et al., 2004; Chen, Zhang, Fang, & Wang, 2013; Hanjabam, Zynudheen, Ninan, & Panda, 2017). Its popularity has increased in recent years due to its high protein and low-fat content. To meet consumer demands, innovative forms of products are being experimented with, incorporating new flavours, using different cuts of meat, and satisfying dietary restrictions such as organic, gluten-free, and nitrate-free products (Han, Lee, Lee, & Kim, 2011).

Jerky is traditionally made from beef, but its high cholesterol content often renders it unsuitable for certain populations, including the obese, elderly, and individuals with heart conditions. As a result, consumers are increasingly seeking alternatives that offer lower cholesterol levels while retaining other nutritional benefits. Squid, as a lean source of protein rich in essential nutrients, emerges as an excellent substitute for beef in jerky production, meeting these health-conscious demands. Additionally, squid's distinctive flavour and nutritional value make it a compelling option for consumers seeking healthier and more diverse food choices (Nurwantoro, Bintoro, & Susanti, 2023).

Beef jerky is traditionally prepared through a drying process, and the same technique can also be effectively adapted for squid meat as a healthier alternative (Chen et al., 2013). Among the various drying methods available, each with its own strengths and weaknesses, microwave drying stands out as a promising option for moisture removal in food materials. Microwave drying works by generating heat internally within the material, leading to enhanced heat transmission and a significantly faster temperature rise than other conventional methods (Khodifad & Dhamsaniya, 2020). This volumetric heating creates vapours inside the food, which migrate outward due to the pressure gradient, reducing the risk of shrinkage during drying (Nair, Li, Gariepy, & Raghavan, 2011). This advantage makes microwave drying particularly suitable

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for preserving the texture and quality of squid meat, which is essential for producing premium squid jerky.

The demand for dried and semi-dried products of marine origin is steadily increasing, driven by their nutritional benefits and distinctive flavors. With this background, the present study, optimized the microwave processing conditions for the development of squid jerky using response surface methodology (RSM). The quality and nutritional evaluation of the microwave processed squid jerky (MPSJ) was also carried out and compared with those of raw marinated squid (RMS).

The squid was purchased from the local fish market in Kochi. The squid were cleaned, tentacles removed, washed and cut into slices of about 3 cm in length and 1 cm in width. The prepared samples were immediately packed, blast frozen, and stored in deep freezer at -18ºC. The other ingredients viz., soy sauce, Worcestershire sauce, garlic powder, onion powder, black pepper, chilli flakes, and salt—were purchased from the local market and used for marinating the product.

The process started with the frozen squid being thawed at 2°C overnight and then marinated with soy sauce, Worcestershire sauce, garlic powder, onion powder, black pepper powder, chilli flakes, and salt. After marination, the samples were conditioned for 2 h under refrigerated condition. Approximately 125 g of the marinated sample was then arranged on drying trays in the microwave drying oven (Model MDR-1601-V5, Enerzi Microwave Systems Pvt. Ltd., India).

A 2^3 factorial experimental design was formulated as shown in Table 1, with different combinations of microwave power (A), temperature (B) and time (C) for drying the marinated samples. A total of eight experimental combinations were conducted for drying process, where moisture content (%, measured as per AOAC, 2019) and overall acceptability (OA, measured on a 9-point hedonic scale) were used as response variables against each experimental combination. A first order response surface regression model with two-factor interactions was fitted to the response variables as a function of microwave power, temperature and time. The functional form of the developed model is given in Equation (1) and the same was used to predict the response variables and to optimize the microwave process conditions using the desirability function. The goodness of fit of the model was assessed using the coefficient of determination (R^2) and the root mean square error (RMSE).

Table 1. Experimental design set up for microwave processed squid jerky (MPSJ)

Factors	Levels	
Microwave Power (W) (A)	400	600
Temperature (ºC) (B)	60	80
Time (Minutes) (C)	45	75

$$Y_u = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 C + \beta_{12} AB + \beta_{13} AC + \beta_{23} BC + e_u,\ u=1,2,\ ---,\ 8,\ ------ (1)$$

Biochemical parameters viz., total volatile base nitrogen (TVB-N), trimethyl amine (TMA), thiobarbituric Acid (TBA), peroxide value (PV), and free fatty acids (FFA), were examined as per AOAC (2019) and AOCS (2005) methods for both the raw marinated sample (RMS) and microwave processed squid jerky (MPSJ). The Hunter Lab MiniScan® XP Plus Spectro Colorimeter (Hunter Associates Laboratory Inc., Reston, VA, USA) was used to estimate the colour of MPSJ and RMS, measuring parameters like L* (lightness), a* (redness/greenness), and b* (yellowness/blueness). To ensure the microbiological safety of the squid jerky, total plate count (TPC) was determined using the spread plate method (Maturin & Peeler, 1998) and the histamine content in microwave processed squid jerky was estimated using the rapid HPLC method (Tsai et al., 2005)

The regression model given in Equation (1) was fitted to the moisture and OA data for squid jerky using the ordinary least square method. The estimated parameters of the fitted model along with the R^2 values are given below for moisture and OA.

Moisture = -72.30 + 0.16*A + 1.79*B + 1.59*C-0.002*AB - 0.001*AC - 0.03*BC; R^2 = 0.92

OA = -11.77 + 0.05*A + 0.14*B + 0.12*C - 0.001*AB - 0.001*AC - 0.002*BC; R^2 = 0.91

It was found that the direct effect of microwave power, temperature and time had a positive effect on the moisture content and OA of the dried squid jerky, whereas their interaction had a negative effect. The reduction in moisture content suggests that the mass transfer within the samples was more rapid with the interaction between higher microwave power, temperature and time due to high heat generated within the chamber. This change in moisture content may have influenced the OA of the microwave dried squid jerky. A similar decrease in moisture content of dehydrated fish products and its influence on sensory score was reported by Murali et al. (2021). Finally, the optimum combination of microwave power, temperature and time for achieving maximum OA and 20% moisture content was found to be 530W at 60ºC for drying time of 50 minutes. The corresponding desirability score was 0.25. The response surface plots of moisture and OA are given in Fig. 1.

Further, the quality and nutritional evaluation of squid jerky prepared under optimum microwave processing conditions was carried out. The initial proximate composition of raw marinated sample was found to be 80.6% moisture, 16.12% protein, 2.30% fat, and 3.39% ash; which changed to 22% moisture, 68.5% protein, 4.63% fat and 5.28% ash, respectively, after the microwave drying process.

The values of all the biochemical quality indices are given in Table 2. The results indicate that values of all the quality indices were within the acceptable limits for dried squid jerky. The comparative evaluation of biochemical quality indices indicates that the values of TVBN, TMA, TBA, and PV for the MPSJ decreased significantly ($p < 0.05$), whereas the FFA value of MPSJ increased significantly compared to the RMS. The increase in FFA after microwave drying indicating higher hydrolysis of glycerol-fatty

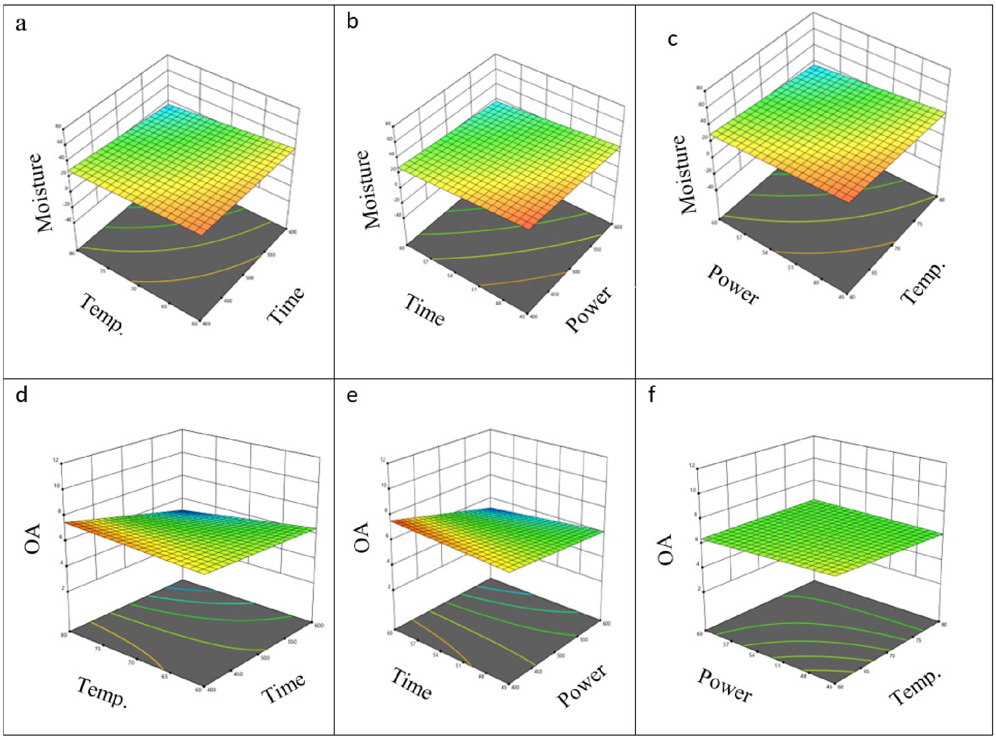

Fig. 1. Response surface plots of moisture (1a. Temperature vs Time, 1b. Time vs Power, 1c. Power vs Temperature) and OA (1d. Temperature vs Time, 1e. Time vs Power, 1f. Power vs Temperature)

Table 2. Mean comparison of biochemical parameters

Samples	TVBN (mg/100g)	TMA (mg/100g)	TBA (mg MDA/kg sample)	PV (mEqO_2/kg oil)	FFA (g/100g, % Oleic acid)
RMS	17.5 ± 0.05^{B}	5.6 ± 0.02^{A}	0.51 ± 0.03^{B}	16.66 ± 0.08^{A}	1.08 ± 0.12^{B}
MPSJ	23.25 ± 0.06^{A}	4.2 ± 0.01^{B}	1.06 ± 0.02^{A}	8.75 ± 0.07^{B}	3.57 ± 0.09^{A}

acid esters (Wan, Zhang, Wang, Mujumdar, & Yong-Jun, 2013).

Means with different letters on the superscript indicate significant difference at 5% level of significance ($p < 0.05$).

The colour parameters of the RMS and MPSJ were measured and are given in Fig. 2. It was observed that microwave drying increased the redness (a*) and yellowness (b*) values of the MPSJ over time, whereas the lightness (L*) value decreased. This might be due to some chemical and biochemical reactions such as browning and lipid oxidation.

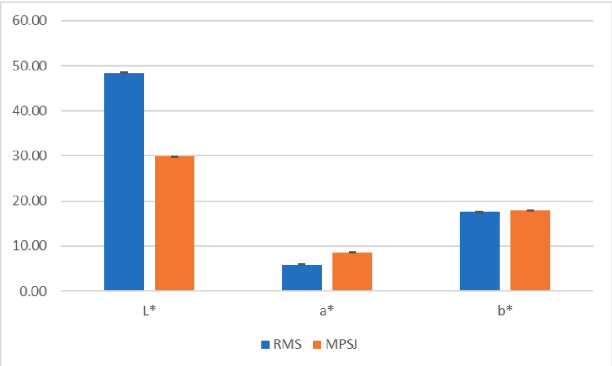

Fig. 2. Comparison of colour parameters of RMS and MPSJ

The TPC of the raw marinated sample was 5.69 log cfu/g, whereas the TPC of the microwave processed squid jerky was 4.60 log cfu/g, which was found to be within the acceptable limits of 6 log cfu/g (Sheng & Wang, 2021). Yeast and mold were absent in the microwave processed squid jerky, indicating that the product was microbiologically acceptable. The histamine content in the microwave processed squid jerky was found to be 24.91 mg/kg, which was well within the acceptable limit as stipulated by Food Safety and Standards Authority of India (FSSAI, 2011).

The sensory evaluation of the microwave processed squid jerky was done by a panel of ten people. The sensory attributes viz., colour, taste, texture, aroma, and OA were recorded in a 9-point hedonic scale. It was found that average OA of the product was 8, with the highest scores (8.4) recorded for taste and aroma. The sensory evaluation score of all the parameters is given Fig. 3.

The study optimized the microwave processing conditions for developing squid jerky, focusing on

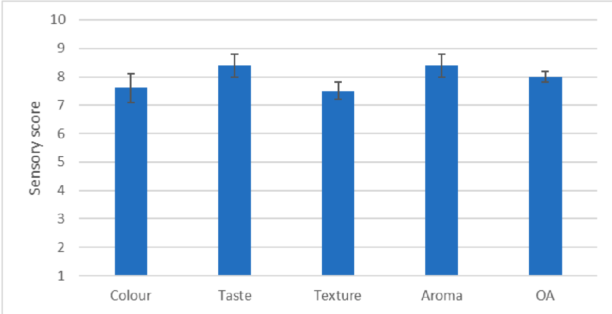

Fig. 3. Sensory evaluation score of MPSJ

moisture content and sensory attributes. The optimal microwave process was determined to be 530W at 60°C for 50 minutes. The nutritional profile and quality evaluation of the squid jerky were assessed, including moisture, protein, fat, and ash content. The microwave drying process significantly enhanced the nutritional value and overall quality of squid jerky.The optimized microwave drying process yielded high-quality squid jerky with improved nutritional content and desirable sensory properties. Biochemical and microbiological analyses confirmed its safety and acceptability. This study highlights the efficacy of microwave drying for producing nutritionally enhanced, shelf-stable squid jerky.

References

AOAC. (2019). *Official methods of analysis of the Association of Official Analytical Chemists: Official methods of analysis of AOAC International* (21st ed.). AOAC, Washington DC.

AOCS. (2005). *Official methods and recommended practices of AOCS* (5th ed.). The American Oil Chemists Society, Urbana.

Chen, H., Zhang, M., Fang, Z., & Wang, Y. (2013). Effects of different drying on the quality of squid cubes. *Drying Technology*, *31*(16), 1911-1918. https://doi.org/10.1080/07373937.2013.783592.

FSSAI. (2011). Food Safety and Standards (Food Products Standards and Food Additives) Regulations, 2011. Food Safety and Standards Authority of India, Ministry of Health and Family Welfare, Government of India.

Han, D. J., Lee, E. S., Lee, S. K., & Kim, C. J. (2011). Effects of hot boning and soy sauce on the processing properties of semi-dried beef jerky. *Food Science of Animal Resources*, *31*(4), 497-505. http://dx.doi.org/10.5851/kosfa.2011.31.4.497.

Hanjabam, M. D., Zynudheen, A. A., Ninan, G., & Panda, S. (2017). Seaweed as an ingredient for nutritional improvement of fish jerky. *Journal of Food Processing and Preservation*, *41*(2), Article e12845. https://doi.org/10.1111/jfpp.12845.

Khodifad, B. C., & Dhamsaniya, N. K. (2020). Drying of food materials by microwave energy-A review. *International Journal of Current Microbiology and Applied Sciences*, *9*(5), 1950-1973. https://doi.org/10.20546/ijcmas.2020.905.223.

Maturin, L., & Peeler, J. T. (1998). Aerobic Plate Count. In *Microbiological Methods & Bacteriological Analytical Manual (BAM)* (8th ed., Revision A). U.S. Food and Drug Administration.

Murali, S., Delfiya, D. S. A., Kumar, K. S., Kumar, L. R. G., Nilavan, S. E., Amulya, P. R., Krishnan, V. S., Alfiya, P. V., & Samuel, M. P. (2021). Mathematical modeling of drying kinetics and quality characteristics of shrimps dried under a solar–LPG hybrid dryer. *Journal of Aquatic Food Product Technology*, *30*(5), 561-578. https://doi.org/10.1080/10498850.2021.1901814.

Nair, G. R., Li, Z., Gariepy, Y., & Raghavan, V. (2011). Microwave drying of corn (*Zea mays L. ssp*.) for the seed industry. *Drying Technology*, *29*(11), 1291–1296. https://doi.org/10.1080/07373937.2011.591715.

Nummer, B. A., Harrison, J. A., Harrison, M. A., Kendall, P., Sofos, J. N., & Andress, E. L. (2004). Effects of preparation methods on the microbiological safety of home-dried meat jerky. *Journal of Food Protection*, *67*(10), 2337-2341. https://doi.org/10.4315/0362-028X-67.10.2337.

Nurwantoro. N, Bintoro V. P., & Susanti, S. (2023). Characteristics of jerky made from ground rabbit meat. *Food Research*, *7*(3), 153-156. https://doi.org/10.26656/fr.2017.7(3).919.

Sheng, L., & Wang, L. (2021). The microbial safety of fish and fish products: Recent advances in understanding its significance, contamination sources, and control strategies. *Comprehensive Reviews in Food Science and Food Safety*, *20*(1), 738-786. https://doi.org/10.1111/1541-4337.12671.

Tsai, Y. H., Kung, H. F., Lee, T. M., Chen, H. C., Chou, S. S., Wei, C. I., & Hwang, D. F. (2005). Determination of histamine in canned mackerel implicated in a food borne poisoning. *Food Control*, *16*(7), 579 -585. https://doi.org/10.1016/i.foodcont.2004.06.019.

Wan, J., Zhang, M., Wang, Y., Mujumdar, A. S., & Yong-Jun, W. (2013). Drying kinetics and quality characteristics of slightly salted grass carp fillets by hot air drying and vacuum microwave drying. *Journal of Aquatic Food Product Technology*, *22*(6), 595-604. https://doi.org/10.1080/10498850.2012.677969.