Optimization of Process Variables of Twin-Screw Extruder Using Response Surface Methodology for the Production of Fish Added Extruded Snack Product

R. Pradeep, K. Rathnakumar, and P. Karthickumar

1 Introduction

The micro and small food processing industries gaining appreciation and acknowledgments from various governmental and non-governmental organizations; nowadays, it helps in achieving sustainable food production with nutritional stability for the nation [1]. Since it enables the opportunities for newcomers to start up a profitable business, Industry 4.0 will also help industries to automate the process and carrying out better management practices to such a trade [2]. The micro and small food industries, besides its small investment, always look further to develop new and innovative products to gain attention and appreciation from the consumers, which led to the competitiveness among the food processors to address the primary concern in any existing food products.

One such product called expanded crisp snack products, commercially called Kurkure, Cheetos, which is a famous snack among all age groups of people because of its lucrative and scrumptious nature [3]. Children are fonded of this snack than adults. The primary concern of this popular snack is lack of nutrition, even it has a high market value. Hence, fortification of such products is needed to improve its nutritional quality up to an acceptable level, which makes the product with a considerable market and nutritional value.

The primary fishery in India includes emperors, seer fish, groupers, tuna, snappers, goat fishes, and anchovies that fetch a reasonable price for fishers. Besides, these enormous quantities of low-value fishes like lesser sardines, oil sardine's sciaenid, skipjack tuna, leather jacket, silver bellies, lizard fishes, catfishes are also landed. However, they are not effectively utilized and predominantly shifted for fishmeal or the dry fish market as fish protein is rich in all essential amino acids irrespective of the size of the fish [4]. Small varieties of fishes are not relished

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because of pin bones and are generally converted into meal for animal feed. Hence, the development of seafood-based snack products can enhance human consumption of these underutilized fishes rather than being utilized for other non-human utilizations [5]. This paves the way to the production of nutritious snacks, as mentioned above, by the addition of low-value fish to high market value snacks.

Several kinds of research were focused on the production of fish added extruded snacks, and its nutritional stability rendered the proper procedure for the production of good nutritional quality extruded snacks [6]. Extruded fish snack products were developed using extrusion technology with cooking formulation consisting of fish flour and cereals mixture were extruded at a moisture content of 15%, screw speed 480 rpm, sectional barrel temperature of 30, 60, 130, and 160 °C at four stages and 2 mm diameter of the die. The extruded product developed was fried using edible oil, and the resulting extruded product was analyzed for a physical characteristic, texture profile, proximate composition, microbiological analysis, and sensory acceptability [5]. However, still commercial fish added extruded snack products are not available in the market because of the less product acceptability and process variable optimization. The color, odor, puffiness, and other sensory properties of fish added extruded snacks are not as same as the higher market value typical extruded snacks. It happens because of the lack of optimization of machine parameters and raw material concentration [7] for the production of extruded fish snack product with high acceptability. The study investigated the effect of feed rate, feed moisture content, screw speed, and barrel temperature on the density, expansion, water absorption index (WAl) and water solubility index (WSI), and sensory characteristics such as hardness and crispness of an expanded rice snack [8] have concentrated machine parameter mainly for its product preparation.

Moreover, another primary concern is the types of machinery for the production of innovative products, for example, fish added extruded snack products. The micro and small food processing cannot afford to buy expensive machinery for every innovative product, and it is unrealistic too. Hence, the optimization of the existing conventional mechanism available already for the production of new and innovative products is necessary for the low capital food processing industry.

This paper aims to achieve such optimization of the very common twin-screw extruder available in every food processing industry for the production of fish added extruded snack products. The quality parameters are optimized by adjusting the process variable of the twin-screw extruder, for the production of good quality and highly acceptable extruded fish snack product.

2 Materials and Methods

2.1 Raw Material Preparation

Fresh lizardfish (Sauridatumbil) was purchased from Akkaraipettai fishing harbor, Nagapattinam. It cleaned, steam boiled (Fig. 1), and then bones removed. The cooked meat was allowed to dry under a temperature of about 50 °C. Then, the dried product was made into powder with the help of a mixer. The fish powder was divided equally and packed in aluminum foil laminated pouches and stored at room temperature. The cornflour (grounded maize kernels purchased on the local market, Nagapattinam) taken in a certain amount according to the trails, and 5% of lizardfish powder added along with it, and other ingredients like salt (2%) and water (10%) added to produce the experimental samples.

2.2 Twin-Screw Extruder

This study was carried out by the twin-screw extruder (M/s. Basic technology, Pvt Ltd, Kolkata, India). It consists of hopper, twin-screw (either co-rotating or counter-rotating in nature), barrel, heating element, die, and cutter. This twin-screw extruder helps us achieve the hot extrusion process very easy to produce the high acceptable puffed snack products. The pitch of the screw made decreasing along its length to apply gradual compression to the food material. Heaters (preferably two) help to achieve the desired temperature, thereby making the food material plastic enough to form the shape of our desire. The specification and image (Fig. 2) of the machine that has used throughout this research is given below.

2.3 Proximate Evaluation

The dried fish powder used for the extruded snack production has to be evaluated for its proximate composition, which has a severe impact on the final product and customer acceptance. Hence, the proximate analysis was done for both fresh fish and dried fish powder. Different laboratory tests conducted at the fish processing incubation center, Keechankuppam, Nagapattinam, to analyze the proximate

Fig. 1 Fresh, cooked, and powdered lizardfish

- Maximum screw speed - 400 rpm
- Capacity – 45 to 50 kg/hr
- No. of heaters – 2
- Power requirement – 440 v, 3 phases

Fig. 2 Twin-screw extruder used for the experiment

composition. Proximate composition viz., protein (AOAC 988.05), moisture content (AOAC 930.15), fat (948.22) and ash (AOAC 186) analyses were carried out according to the mentioned procedures.

2.4 Design of the Experiment

The experiment designed with the principal aim to optimize the process variables for the production of good quality extruded snack products. The values of process variables are fixed within the specified operating range decided by the capacity of the twin-screw extruder. The input machine variables like screw speed and heater temperature 1 and 2 are randomly selected for 28 trail sets within the operating ranges.

The quality and acceptability of the products rely on specific physical and sensory responses like expansion ratio, texture, color, bulk density, true density, and 50 product weights. Thus, an experiment is conducted with the 28 sets of different input machine parameter combinations, as discussed earlier. The responses of each trial are recorded and analyzed with design expert software version 11, which helps to optimize the machine parameters to get the desired product qualities. One additional parameter of maize concentration was also added as the input parameter since it also has its impact on the goodness of product developed.

Expansion ratio: Randomly selected 20 extruded samples subjected to this test. The diameter of the extruded samples measured with vernier caliper (M/s. Kannan Hydrol & tools, Chennai), from which the average diameter of the extruded snacks calculated. The expansion ratio calculated by the ratio of the average diameter of the product to the diameter of the die [9].

Sensory evaluation of extruded snack: Sensory evaluation of extruded snacks was carried out by a panel of 30 subject experts available in the College of Fisheries Engineering, Nagapattinam. They were asked to indicate their opinion on a 9-point hedonic scale (9 for extremely liked product to 1 for dislike extremely). The experts analyzed each product for its appearance, color, flavor, taste, and overall acceptability of the product.

Bulk density: Randomly selected 20 extruded samples considered for this test. The diameters of the extruded samples measured with Vernier caliper, from which the average radius of the extruded snacks calculated. Assuming the shape of the extruded snacks to be cylindrical, extruded snacks, the total volume was calculated by adding the individual lengths of 20 extruded samples. The bulk density calculated by dividing the average weight by the volume of extruded samples given in Eq. (10) [11].

$$\text{Bulk density} = \text{Weight}/\text{Volume of extruded samples} \tag{1}$$

True density: True density of the extruded product calculated by the mustard replacement method. In this method, extruded products filled up to a specific volume with the air voids between the products. After that, air voids filled with the mustard, and the volume occupied by the mustard calculated, and this volume subtracted from total volume occupied by the extruded products. Finally, the total weight of the product is divided by the reduced volume to find the true density of the extruded products given in Eq. (1) [12].

$$\text{True density} = \text{Weight}/\left(\text{Total volume} - \text{mustard volume}\right) \tag{2}$$

50 Product weight: 50 Product weight of the sample taken by measuring the weight of randomly selected 50 extruded products. It shows that the product will be more acceptable if this weight is minimal [11].

2.5 Response Surface Methodology

Response surface methodology is the technique to optimize the process variables systematically. Since most of the innovative foods products developed from modern machinery in food industries are lagging in its acceptability by the people, because of the inappropriate knowledge about the machine with its process variables for a particular product. This technique identifies the relationship between various machine parameters and their interaction. The specific technique called Box-Behnken mechanism applied to this problem, which helps us to find the right process variable in the particular range of operating conditions of twin-screw extruder

2.6 Box-Behnken Mechanism

It is the set of techniques applied to a controlled experiment to study the influence of different variables in the outcome [13]. Generally, the first step is identifying the independent variable or factors that affect the product or process and then studying their effects on dependent variables or the response.

It uses the corner selection, face, and central points by considering experimental space with fewer points. It is less expensive to run with the same number of factors. It can able to estimate efficiently first- and second-order coefficients.

3 Results and Discussion

3.1 Proximate Analysis

This study mainly concentrates on producing the acceptable quality in terms of sensory and physical characteristics of the product, which requires the actual nutritional composition of the raw material for better understanding to maintain the same nutritional quality after the extrusion process. The proximate analysis of both fresh and powdered fish conducted, and the result obtained as given below in Table 1. The results obtained are satisfactory enough to produce a nutritionally acceptable product. At the same time, it can accommodate the process of extrusion in all possible ways to create a product of acceptable quality. Previous studies reported the quality of fish [14] was satisfactory. The fish contains 1% fat used in this study, which helps to withstand the barrel's temperature without affecting the final product quality. For product quality, the responses recorded given in Table 2, which includes both physical and sensory responses of the product developed. The significance of developed model is given in Table 3, and coefficients of the process variable of the developed model are given in Table 4.

Table 1 Proximate composition of lizardfish analyzed at fresh and powdered state

S. no.	Parameters	% composition in fresh fish	% composition in powdered fish
1	Moisture	76.99	6.02
2	Protein	19.01	89.63
3	Fat	1.13	1.05
4	Ash	1.31	2.06

Expansion ratio: The expansion ratio is the decisive factor that always helps to improve the crunchy nature of the product. It is an important parameter to be considered for the better quality of the final product [15]. It is observed from Table 3 that the expansion ratio is significantly affected by heater temperature 2 linearly. It shows that the increase in temperature just before the die helps in achieving the increase in expansion ratio up to a certain level. The researchers obtained similar results in making puffed snacks from different ingredients [16–18].

The expansion ratio of the product is also quadratically affected by the screw speed. It gives us a clear view that the increase in screw speed, eventually increases the expansion ratio of the product (Fig. 3). A similar interpretation was found with carrot pomace as an ingredient for an extruded snack. The expansion ratio of the final product is controlled by varying the heater temperature 1 and 2.

Texture: The texture of the product is a sensitive indicator that meets the exceptional quality to be acceptable by consumers. From Table (11), it is affected quadratically affected by heater temperature 1 and 2. The same instance was recorded in [10]. Figure 4 confirms the set temperature for producing fish added extruded snack product and helps to obtain a good texture.

Color: The color is also a sensory attribute and an indirect measure of the quality of the product. The consumer choice of preference must play a vital role in judging this parameter. Since this experiment purely based on expert's survey on all 28 samples, the result could orient towards the high acceptable color of the product. The results obtained in Table 3 show that the color of the product is affected by linearly and quadratically on heater temperature 1. Figure 5 also supports the justification well with the effect of heater temperature against color.

Bulk density: It is the responsible parameter for the space occupancy of the product in the package. Since it has some more advantages in the packaging and logistic aspects, the product with considerable bulk density will help in the reduction of packaging cost. It is observed from Table 3 that it is affected linearly by heater temperature 1 and quadratically by screw speed. Bulk density of the product is induced by screw speed and heater temperature in a particular way (Fig. 6).

True Density: It plays a vital role in deciding the absolute matter in the product, which helps in determining the actual nutritional quality of the product. From Table 3, the true density is affected linearly by heater temperature 1 and quadratically by heater temperature 2 and screw speed. Figure 7 depicts the same above-said justification.

Table 2 Experimental trails with recorded responses

Sample	Screw speed (rpm)	Heater 1 temperature (°C)	Heater 2 temperature (°C)	Maize content (g)	Expansion ratio	Texture	Color	Bulk density (kg/m^3)	True density (kg/m^3)	50 product weight
1	250	60	100	110	3.3	3.2	4.4	150.88	251.46	13.48
2	350	60	100	80	3.36	5.5	5.5	84.3	126.45	13.85
3	350	80	100	110	3.16	3.4	3.5	166.23	249.35	14.29
4	300	70	105	95	3.49	5.8	7	140	200	28.05
5	250	80	100	80	3.59	7	5.3	74.79	123.94	13.55
6	300	70	105	95	3.69	5.5	6.9	113.4	195.52	22.5
7	250	80	110	110	3.2	3.3	4.6	210.56	310.5	12.68
8	350	80	110	80	3.38	3.3	5.3	220.4	305.8	12.25
9	350	60	110	110	3.61	7.8	7.8	75	150	13.25
10	250	60	110	80	4.16	6.6	6.9	105.03	152.3	13.91
11	250	60	110	110	4.14	7	8	91.16	136.75	12.34
12	350	80	100	80	3.73	7.25	5	78.23	134.11	14.04
13	250	80	100	110	2.86	3	3.75	177.4	266.1	12.72
14	350	80	110	110	3.55	3.5	4.5	178.46	237.95	17.83
15	350	60	100	110	2.89	4.8	5.3	106	181.71	13.38
16	300	70	105	95	3.52	6.3	6.3	98.83	156.05	21.44
17	350	60	110	80	3.64	6.8	8.8	70.03	105.05	24.54
18	250	60	100	80	3	6.5	3.3	103.5	147.85	8.27
19	300	70	105	95	3.19	6.8	6.8	128.33	220	19.37
20	250	80	110	80	3.26	5.8	3.5	158.4	264	14.6
21	300	70	115	95	3.08	5	4.5	221.65	354.64	13.18
22	300	70	105	125	3.16	5	3.8	200	300	10.09

(continued)

Table 2 (continued)

Sample	Screw speed (rpm)	Heater 1 temperature (°C)	Heater 2 temperature (°C)	Maize content (g)	Expansion ratio	Texture	Color	Bulk density (kg/m^3)	True density (kg/m^3)	50 product weight
23	300	70	105	95	3.3	8.25	8	124.6	213.6	22.18
24	300	70	105	65	2.99	6.5	5.5	176.85	353.7	9.97
25	300	70	95	95	2.98	4	2	254.46	386.52	14.54
26	300	50	105	95	3.05	3.8	2	178.5	214.83	15.37
27	300	90	105	95	3.07	4.3	3	209.9	419.8	13.47
28	300	70	105	95	3.5	7	8.8	105.66	181.14	22.02

Table 3 Significance values of the model developed for every response with significant terms

Source	Expansion ratio	Texture	Color	Bulk density	True density	50 product weight
Model	0.0360	0.0068	0.0044	0.0005	0.0002	0.0152
A-screw speed	0.8479	0.6439	0.3302	0.3822	0.3144	0.1067
B-heater temperature 1	0.2838	0.0609	0.0244	0.0009	<0.0001	0.7583
C-heater temperature 2	0.0171	0.3101	0.0015	0.4325	0.5469	0.3466
D-maize content	0.3847	0.0334	0.1347	0.0298	0.1195	0.7612
AB	0.0590	0.8447	0.1231	0.2046	0.5813	0.3531
AC	0.3362	0.9589	0.6943	0.6314	0.8351	0.5993
AD	0.6945	0.4444	0.4283	0.2817	0.4206	0.5982
BC	0.0095	0.0069	0.0132	0.0030	0.0061	0.3477
BD	0.3362	0.2895	0.1175	0.1948	0.7632	0.3911
CD	0.1392	0.0154	0.9458	0.0260	0.0208	0.3092
A^2	0.0162	0.1084	0.6924	0.0001	<0.0001	0.3826
B^2	0.0720	0.0006	0.0013	0.0032	0.0019	0.0074
C^2	0.0548	0.0025	0.0043	<0.0001	<0.0001	0.0048
D^2	0.0823	0.0398	0.1030	0.0054	0.0011	0.0003

50 product weight: This response is essential for the purpose when it comes to the packaging of the products. In the packaging area, the product weight plays a vital role in determining the package quantity, so by the economic view, this has to be optimally higher to achieve more benefits. From Table 3, it is understood that the quadratic factor of heater temperature 1 and 2 affects 50 product weight significantly. Figure 8 proves the dependency of 50 product weight on temperature 2 along with maize content. The temperature given to the raw material determines the weight of puffed snacks in addition to the maize concentration in it [17].

Among the process parameters, controlling the expansion ratio is a bit complicated than any other, since the expansion ratio is an essential parameter in deciding the product's ultimate quality. It is optimized with higher importance than any different response.

3.2 *Optimization*

The optimum condition was then determined using the Box-Behnken mechanism. The final acceptable product should have an increased expansion ratio, representing all other parameters with adjusted input values, and also, its model significance

Table 4 Process variable coefficients of the developed model for different responses

	Expansion ratio	Texture	Color	Bulk density	True density	50 product weight
	−63.78988	−476.63484	−472.90567	14767.74312	19803.50083	−1414.61606
A	−0.054925	−0.212750	0.082292	11.86261	24.58295	0.288742
B	0.480583	3.72354	2.82125	−84.14025	−110.52529	4.46746
C	1.11533	7.95042	6.47917	−266.39483	−383.64592	20.08975
D	0.019991	−0.670509	0.481435	7.47919	10.46917	3.65176
AB	0.000251	−0.000119	−0.000744	0.017176	0.010977	−0.001520
AC	−0.000243	−0.000063	−0.000363	0.012638	0.008245	0.001700
AD	−0.00032	0.000313	−0.000246	−0.009629	−0.010760	−0.000568
BC	−0.003687	−0.019062	−0.012937	0.468287	0.635150	−0.015375
BD	−0.000404	−0.002119	−0.002521	0.058604	0.019908	0.004667
CD	0.001275	0.011042	−0.000208	−0.215308	−0.340183	−0.011133
A^2	0.000109	0.000335	0.000060	−0.022656	−0.042330	−0.000466
B^2	−0.000971	−0.010917	−0.007479	0.18925	0.307325	−0.020433
C^2	−0.004183	−0.036167	−0.025417	1.19585	0.307325	−0.087333
D^2	−0.000415	−0.002463	−0.001435	0.077728	1.76195	−0.013959

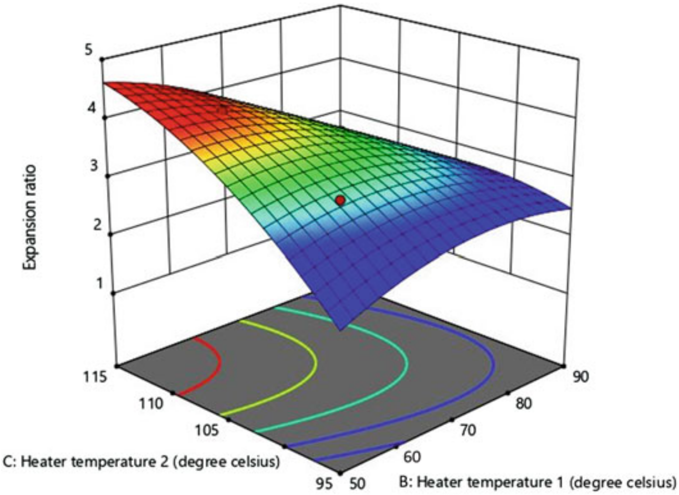

Fig. 3 Effect on expansion ratio—H2 versus H1

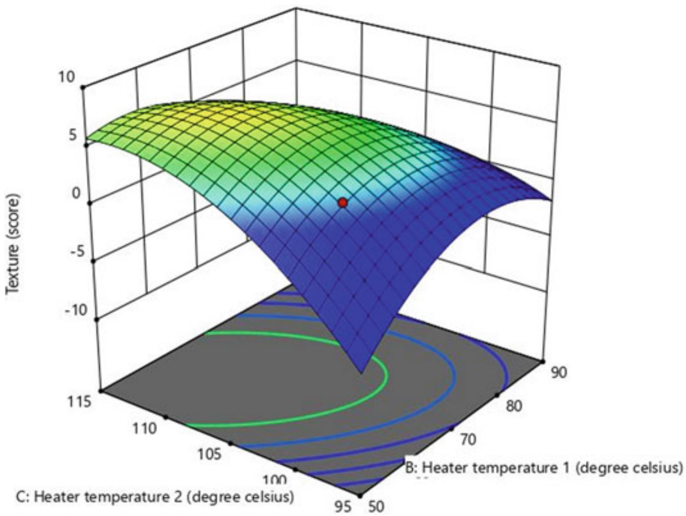

Fig. 4 Effect on texture—H2 versus H1

value is comparatively less than the different response model, as in Table 4. The emphasis placed on the expansion ratio, but the other parameters are maintained at the same level of importance to achieve the product of acceptable combination. The two best possible combinations derived from optimization for producing the product of high acceptability in twin-screw extruder within the operating range given

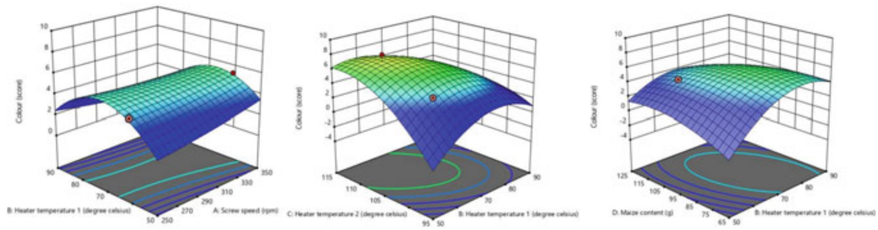

Fig. 5 Effects on color—H1 versus other variables

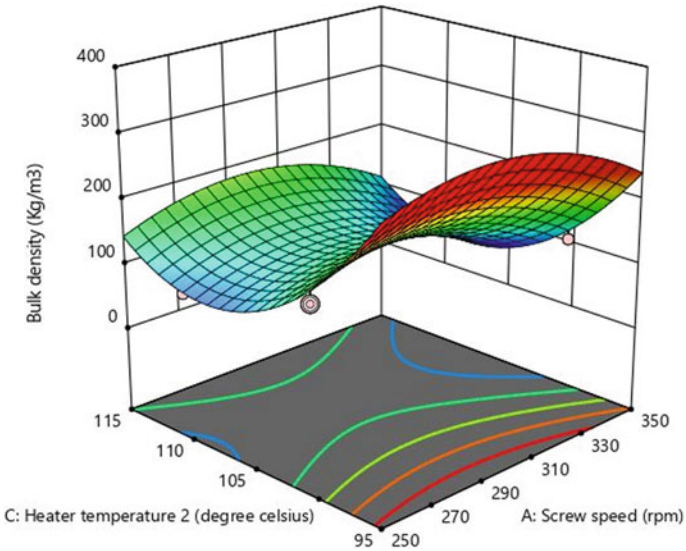

Fig. 6 Effects on bulk density—H2 versus screw speed

in Table 5. It was compared with the derived results in the optimization process. The accuracy of the optimized model is 95.31% for importance 4 and 93.68% for importance 5.

4 Conclusion

The nutrition-rich expanded crisp porous snack produced from the mixture of lizardfish, rice flour, and corn. This snack gaining recognition and appreciation due to their ready to eat nature, delicious taste, and appealing look. This paper is addressed and designed in a particular way to eliminate this issue by optimizing the most popular twin-screw extruder in its approach for producing the product of our

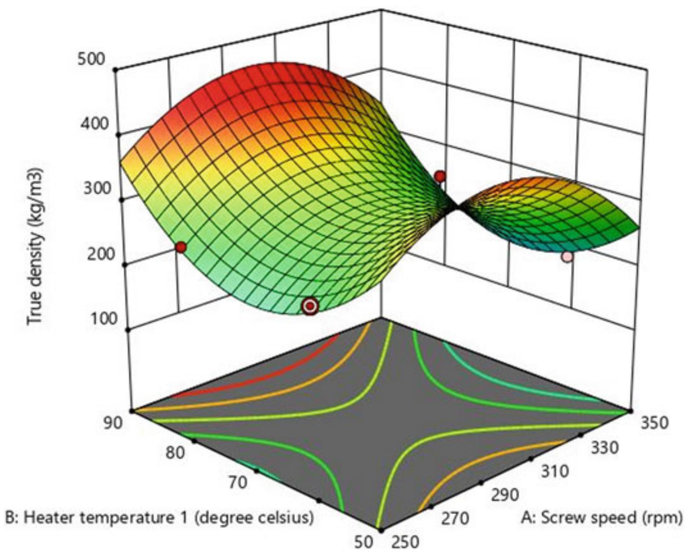

Fig. 7 Effects on true density—H1 versus screw speed

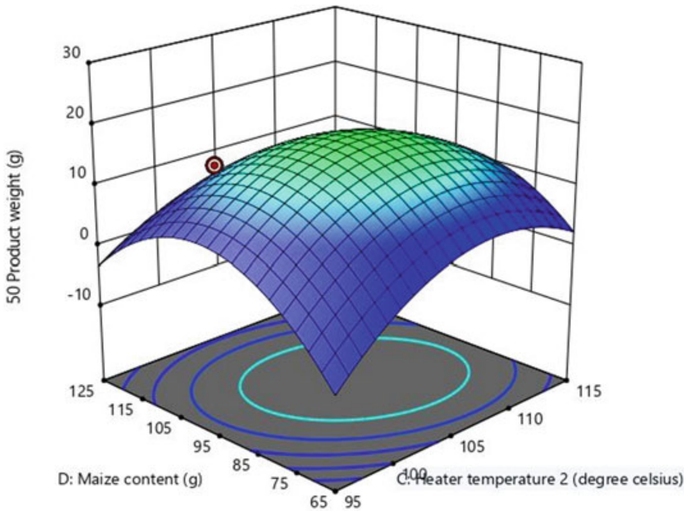

Fig. 8 Effect on 50 product weight—maize content versus H2

interest. This study determined the process condition for any food processing industries to formulate their combination for the production of nutritious and high market demand product called an extruded fish snack. In the future, this optimization may be included in the machine itself with the help of modern techniques

Table 5 Box-Behnken optimization and comparison with experimental results

	Importance 4		Importance 5	
Parameters	Obtained value	Experimental run	Obtained value	Experimental run
Screw speed	350.000		250.000	
Heater temperature 1	54.007		57.890	
Heater temperature 2	113.277		110.764	
Maize content	113.502		107.852	
Expansion ratio	3.763	3.98	4.227	4.32
Texture	7.459	7.8	6.991	7.5
Color	7.586	8	7.071	7.8
Bulk density	70.018	72.812	91.726	93.46
True density	125.143	124.8	129.160	132.4
50 product weight	8.270	9.09	11.134	13.15
Accuracy	0.9531		0.9368	

like programmable logic controller (PLC), which makes the machine intelligent enough to produce the high acceptable extruded fish snack product.

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References

1. Avermaete T, Viaene J, Morgan EJ, Crawford N (2003) Determinants of innovation in small food firms. Eur J Innov Manage 6:8–17
2. Corallo A, Latino ME, Menegoli M (2018) From industry 4.0 to agriculture 4.0: a framework to manage product data in agri-food supply chain for voluntary traceability. Int J Nutr Food Eng 12:146–150
3. Method of making an expanded crisp snack food product (1973)
4. Kinsella JE, Melachouris N (1976) Functional properties of proteins in foods: a survey. Crit Rev Food Sci Nutr 7:219–280
5. Mulye VB, Zofair SM (2015) Utilization of croaker (Johnius dussumieri) to develop ready to eat puff snack product using extrusion technology. Food Sci Res J 6:184–191
6. Shaviklo GR, Olafsdottir A, Sveinsdottir K, Thorkelsson G, Rafipour F (2011) Quality characteristics and consumer acceptance of a high fish protein puffed corn-fish snack. J Food Sci Technol 48:668–676
7. Yağcı S, Göğüş F (2008) Response surface methodology for evaluation of physical and functional properties of extruded snack foods developed from food-by-products. J Food Eng 86:122–132

8. Ding Q-B, Ainsworth P, Tucker G, Marson H (2005) The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based expanded snacks. J Food Eng 66:283–289
9. Korkerd S, Wanlapa S, Puttanlek C, Uttapap D, Rungsardthong V (2016) Expansion and functional properties of extruded snacks enriched with nutrition sources from food processing by-products. J Food Sci Technol 53:561–570
10. Ajita T (2018) Extrusion cooking technology: an advance skill for manufacturing of extrudate food products. In: Extrusion of metals, polymers and food products
11. Case SE, Hamann DD, Schwartz SJ (1992) Effect of starch gelatinization on physical properties of extrused wheat-and corn-based products. Cereal Chem 69:401–404
12. Thymi S, Krokida MK, Pappa A, Maroulis ZB (2005) Structural properties of extruded corn starch. J Food Eng 68:519–526
13. Ferreira SC, Bruns RE, Ferreira HS, Matos GD, David JM, Brandao GC, da Silva EP, Portugal LA, Dos Reis PS, Souza AS (2007) Box-Behnken design: an alternative for the optimization of analytical methods. Anal Chim Acta 597:179–186
14. Rathnakumar K, Pancharaja N (2018) Development of health mix from lizard fish and its nutritional characteristics. Int J Curr Microbiol App Sci 7:3136–3144
15. Thachil MT, Subrato B, Chouksey MK, Gudipati V (2016) Modeling the inclusion of fish powder and fish oil into extruded snacks by response surface methodology. J Aquat Food Prod Technol 25:46–64
16. Giménez MA, González RJ, Wagner J, Torres R, Lobo MO, Samman NC (2013) Effect of extrusion conditions on physicochemical and sensorial properties of corn-broad beans (Vicia faba) spaghetti type pasta. Food Chem 136:538–545
17. Hagenimana A, Ding X, Fang T (2006) Evaluation of rice flour modified by extrusion cooking. J Cereal Sci 43:38–46
18. Yu L, Ramaswamy HS, Boye J (2012) Twin-screw extrusion of corn flour and soy protein isolate (SPI) blends: a response surface analysis. Food Bioprocess Technol 5:485–497