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Extruded snacks from rice, green lentil, chickpea and tomato powder finished with frying/microwave roasting

Pasabocas extruidos de arroz, lenteja, garbanzo y tomate en polvo fritos o horneados en microondas

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ABSTRACT: Extrudates were first prepared through extrusion-cooking and air-drying of different formulations obtained through a D-optimal Mixture Design containing blends of rice flour (RF), green lentil flour (GL), chickpeas flour (CP), and tomato powder (TP) in different proportions. These extrudates were subjected to deep oil frying (DOF) at 200□C or microwave roasting (MWR) at 75% power level (1000W oven) in order to develop desirable color and flavor characteristics. Physical properties including color (L*, a*, b*), expansion ratio (ER), breaking stress (BS) and antioxidant activity (AA) were evaluated, and the influence of product variables on output parameters was assessed. Increasing CP and GL in the formulations resulted in a decrease in the ER and an increase in the BS. However, the inclusion of CP and TP helped to produce snacks of golden yellow color and increased their overall acceptability. The addition of TP also improved the antioxidant activity of the resulting product. Both DOF and MWR resulted in a lower antioxidant activity; however, MWR led to more than 80% retention of the original antioxidants and higher sensory acceptability. ER and L* values had a strong positive correlation with the overall acceptability of products. The extrusion - air-drying - microwave roasting process produced healthy snacks with acceptable sensory quality, high protein (through added pulses), and enriched antioxidant (through added tomato powder) contents.

RESUMEN: Se extruyeron diferentes formulaciones de pasabocas de harina de arroz (RF), harina de lentejas verdes (GL), harina de garbanzo (CP) y tomate en polvo (TP) y se sometieron a freído en aceite (DOF) a 200°C o horneado en microondas (MWR) a un nivel de potencia del 75% (horno de 1000 W) para desarrollar las características de color y sabor requeridas. El color (L *, a *, b *), la relación de expansión (ER), el estrés de rotura (BS) y la actividad antioxidante (AA). El aumento de las harinas CP y GL en las formulaciones resultó en una disminución en ER y un aumento en BS. Sin embargo, la inclusión de CP y TP ayudó a producir pasabocas de color amarillo dorado y a aumentar su aceptabilidad. La adición de TP mejoró el AA. Tanto la DOF como la MWR disminuyeron la AA; sin embargo, MWR retuvo las propiedades sensoriales y AA más del 80%. El ER y L * tuvieron una fuerte correlación positiva con la aceptabilidad general de los productos. En general, el secado por extrusión seguido de MWR produjo pasabocas saludables con una calidad sensorial aceptable, alto contenido de proteínas (a través de legumbres agregadas) y antioxidantes enriquecidos (a través de TP agregado).

1. Introduction

Convenience foods have become part of today's lifestyle of people with the introduction of a variety of ready-to-eat meals. Such foods are getting popular because they need little or no processing before being consumed. The consumption of ready-to-eat food such as snack foods has become so frequent and significant that it is even replacing regular meals of the day [1, 2]. Snacks in the marketplace today are generally based on high energy, carbohydrate-rich, plant products (usually 400-500

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Kcal/100 g) and are low in contents of other essential nutrients required for body growth and development [3]. Hence, the production of nutrient-dense snack foods with better sensory acceptability is an essential alternative.

Among various methods used to prepare snacks, the short-time extrusion-cooking at high-shear, high-temperature, and high-pressure processing has been widely recognized. However, the success of such an extrusion process depends on multiple processes and product variables and needs to be optimized in order to get the best product quality [4, 5]. In some extruded snacks, the products after extrusion and drying, will not attain its final desired sensory characteristics. Such dried extrudates have the advantage of long shelf life (due to low water activity). However, they need to have a finish treatment (like cooking, frying, roasting, etc.) which can be implemented when needed [6] to achieve the desirable physical, chemical, and sensorial changes to increase their consumer acceptability.

Ingredients like green lentils (GL) and chickpea (CP) are cool-season legumes and are grown in Canada on a large scale. Especially, Pulse Canada based in Winnipeg, Manitoba has now become the largest exporter of pulse crops [7, 8]. Both green lentils and chickpeas have many health-promoting benefits like prevention of cardiovascular disease [9–11], cancer [12], lowering of glycemic index, and preventing diabetes [13]. CP and GL are rich sources of proteins and provide significant amounts of vitamins and minerals. Mudryj *et al.* [14] reported that even $1/2$ a cup of pulses in our diet can help increase the nutrient intake of proteins, thiamin, vitamin B6, folate, iron, magnesium, phosphorus, and zinc by substantial amounts. CP is a rich source of essential fatty acids, and hence the incorporation of various pulse flours will help in the production of nutrient-dense snack foods. Proteins are not only required to increase the nutritional quality of snack, but they also play an important role in flavor formation through reaction with reducing sugars and giving Maillard browning compounds.

Reactions during high-temperature processes, reactions involving hydrogen bonding, development of amino acid-reducing sugar complexes and covalent bonding among amino acids can lead to browning and flavor changes. Apart from the formation of protein complexes and protein denaturation, starch gelatinization is an essential process of the snack production process. In general, starch forms the main structure of snacks and is responsible for water holding and puffiness through expansion in volume [15]. The starch matrix and protein-starch structure lead to significant product quality variations by crisp texture and color development and by governing oil uptake during frying. For determining the acceptability of snack products, sensory acceptance tests are widely used in the food industry and are considered the core of a quality control program. It guides product development and helps improve, optimize, and maintain production [16].

The extrusion drying process followed by deep fat frying (DOF) or microwave roasting (MWR) enables several variables to interact together, and hence outcomes might vary with different products and process variables. However, the effect of such processes on physical and sensorial properties and antioxidants retention of rice-pulse-tomato formulations has not been studied yet. Thus, the focus of this study was to a) evaluate and optimize the extrusion air-drying process of formulations from blends of rice flower (RF), GL, CP, and tomato powder (TP) through response surface methodology to produce healthy snack foods and b) to optimize the finish treatment conditions (DOF and MWR) based on physical and sensory properties.

2. Materials and methodology

2.1 Materials

Rice flour (RF) and green lentil flour (GL) were purchased from a local store (Bulk Barn, Montreal, Canada) with rice flour composition mentioned by the manufacturer as protein: 5%, fat: 1.25%, carbohydrate: 80%, and dietary fiber: 2.5% and GL with manufacturer composition as protein: 36%, fat: 1.25%, carbohydrate: 60% and dietary fiber: 2.5%). Chickpea flour (CP) (Well Canada, Ontario) contained the following: protein: 20%, fat: 6.66%, carbohydrate: 60% and dietary fiber: 16.65%. Tomato Powder (TP) (Z Natural Foods, Florida, USA) having labelled composition as protein: 13%, fat: 0%, carbohydrate: 75% and dietary fiber: 16%. For frying the extrudates, canola oil available commercially was used.

2.2 Preparation of dried extrudates

Twenty formulations (experimental conditions) were obtained by D-optimal mixture design using the Design Expert software (Version 9.0.3 State-Ease, Inc., Minneapolis, MN), considering four variables at predetermined levels (Table 1). The independent product variables used in this study were RF, GL, CP, TP. For minimizing the effect of experimental errors, replicate points were included, and experiments were performed in a random error based on the experimental design. Each 500 g batch was prepared by adding 94 g water and a small amount of salt to 400 g blend formulation (Table 1) using a mixer (Hobart Food Equipment Group Canada, North York, ON) for 15 min, and mixtures were packed in plastic bags and held overnight at 4°C for the moisture equilibration.

Hydrated blends were fed (200 g/min) to a twin-screw extruder (DS32-II, Jinan Saixin Food Machinery, Shandong, P. R. China) equipped with three independent zones of controlled temperature all set at 22°C (screw speed 120 rpm). The diameter of the screw was 30 mm, and the length to diameter ratio of the screw was 20:1. The die shape was circular, and the diameter and length were 5 and 27 mm, respectively. Extrudates were cooled under gentle air-flow (22°C) conditions overnight, and then the finish drying was carried out at 55□ C and 0.1 m/s air flow rate to achieve a final moisture content of 18% (dry basis). After drying, samples were put in airtight containers and stored in a dark place at room temperature for further analysis. The extruded samples were also processed, further either by frying or microwave roasting for sensory quality enhancement using the procedures mentioned in Section 2.3.

2.3 Post extrusion-drying processes for enhancing sensory properties

Deep Oil Frying (DOF)

The extruded products were pre-cut in cylindrical shapes of 5 cm length and then subjected to deep oil frying using 2 L canola oil in a digital pot fryer (T-Fal FR4017 Deep Fryer, NJ) for different time (every 10 s time interval from 30 s to 90 s) and oil bath temperature (160, 180, 200, and 220 (□C)) combinations. The products were withdrawn at 10 s intervals starting from 30 to 90 s, and excess oil was blotted out using a paper towel. Samples were allowed to reach equilibrium and then transferred to a plastic container to carry out further analysis.

Microwave roasting (MWR)

Extrudates were pre-cut into 5 cm length cylinders, and MW treated at different power levels for different treatment times. A microwave oven (1100W, 2450MHz, Panasonic, China) was used, and samples were treated at 4 power levels (25%, 50%, 75%, or 100%), and withdrawn 10 s intervals starting from 20 s and up to 90 s.

2.4 Measurement of physical characteristics

Color

The color of the extrudate pieces was determined with the help of a bench-top Minolta CM-500d colorimeter (Optical Sensor, Hunter Associates Laboratory Inc., Reston VA, USA) which used an aperture of diameter 1.2 cm and L* (lightness), a* (redness to greenness) and b* (blueness to yellowness) were reported as the mean value of triplicate measurements [17]. The unit was warmed up for 30 min prior to measurements.

Expansion ratio (ER)

The expansion ratio of 10 replicate extrudate samples was measured by measuring the diameter of the extruded sample using a Vernier caliper and computing the ER using Equation 1 and then averaged. ER was calculated as [18]:

$$ER = \frac{\text{Diameter of the extrudate sample}}{\text{Diameter of the die hole}} \tag{1}$$

where the diameter of the die hole was 5 mm.

Rehydration ratio (RR)

For the determination of rehydration ratio, 15 g of air-dried extrudate sample was taken and placed in a beaker containing 500 ml of water at room temperature. After holding it for 15 min, water from the beaker was drained out, and the collected extrudate was immediately weighed (Equation 2). The rehydration ratio (RR) was calculated as [19]:

$$RR = \frac{\mathrm{w}_2 - \mathrm{w}_1}{\mathrm{w}_1} \tag{2}$$

where W1 and W2 represented the weight of the extrudates before and after rehydration, respectively.

Breaking stress (BS)

A 3-point bending test was employed using a texture analyzer (TA-XT2, Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK) equipped with a load cell of 20 kg. Extruded samples were placed on two round metal rods securely placed 30 cm apart on the measuring platform of the texture analyzer. A 2 mm diameter cylindrical probe pushed the sample across at the central point at a rate of 40 mm/min until the sample was broken. The pressure required to bring the break was recorded as the breaking stress and expressed as the force (N) required per unit cross-section area (mm2). The breaking stress of ten replicated samples was calculated, and then the average was taken [20].

Antioxidant activity (AA)

The antioxidant activity (AA) of extrudates was determined using the DPPH free radical scavenging assay method. The method was adapted from Martínez-Valverde *et al.* [21]. First, to prepare methanolic extracts, a 0.1 g of sample was taken in 0.9 ml of methanol. The solution was prepared in a 1.5 ml Eppendorf. For extraction of antioxidants, the sonication of the solution was done in the dark for 30 min, and after that, the samples were centrifuged at 4000 rpm for 15 min to separate the supernatant and the extract; the supernatant was collected, and methanol was then again added to centrifuge pellet for extraction, and

Table 1 Experimental runs generated with D-optimal mixture design with (actual) values of product variables for a batch of 400 g feed mix (excluding salt and water proportion)

Run	Rice % (g)	Lentil % (g)	Chickpea % (g)	Tomato Powder % (g)	Calculated Protein % (g)	Moisture Content (% wb)
1	33 (132)	33.5 (134)	30 (120)	3.5 (14)	17.48 (69.93)	27.34
2	52.8 (211)	28.33 (113)	17.08 (68)	1.75 (7)	14.75 (59.00)	27.19
3	41.5 (166)	28.5 (114)	30 (120)	0 (0)	16.34 (65.38)	27.19
4	60 (240)	20 (80)	16.5 (66)	3.5 (14)	13.21 (52.86)	27.24
5	39.3 (157)	36.33 (145)	22.58 (90)	1.75(7)	16.95(67.83)	27.24
6	33 (132)	45 (180	22 (88)	0 (0)	18.41 (73.64)	27.19
7	33 (132)	45 (180)	15 (60)	7 (28)	17.91 (71.65)	27.44
8	33 (132)	45 (180)	15 (60)	7 (28)	17.91 (71.56)	27.44
9	50.8 (203)	35.75 (143)	10 (40)	3.5 (14)	15.33 (61.33)	27.25
10	60 (240)	23 (92)	10(40)	7 (28)	13.14 (52.57)	27.35
11	43 (172)	20 (80)	30 (120)	7 (28)	15.15 (60.61)	27.44
12	60 (240)	30 (120)	10 (40)	0 (0)	14.05 (56.21)	27.10
13	51.5 (206)	20 (80)	21.5 (86)	7 (28)	14.06 (56.24)	27.40
14	60 (240)	30 (120)	10 (40)	0 (0)	14.05 (56.21)	27.10
15	60 (240)	23 (92)	10 (40)	7 (28)	13.14 (52.57)	27.35
16	33 (132)	45 (180)	22 (88)	0 (0)	18.41 (73.64)	27.19
17	33 (132)	33.5 (134)	30 (120)	3.5 (14)	17.48 (69.93)	27.34
18	44.5 (178)	30.5 (122)	18 (72)	7 (28)	15.58 (62.32)	27.41
19	41.5 (166)	45 (180)	10 (40)	3.5 (14)	17.06 (68.27)	27.27
20	50.0 (200)	20 (80)	30 (120)	0 (0)	14.75 (59.00)	27.16

Note: The level of salt and water added was the same for each run; 6 g of salt and 94 g of water was added to each batch of 400

hence the procedure was repeated, and the supernatant was collected again. This supernatant was the methanolic extract used for examining DPPH scavenging activity. For this, 1 mM solution of DPPH was prepared in methanol (40 mg in 100 ml methanol). The DPPH solution was prepared fresh every time. After this, the Trolox standard curve was plotted using different Trolox concentrations (0-500 µm). The methanolic extract was taken in 100 µl quantity and was added to 1.5 ml of DPPH solution. After this, it was kept in the dark for 30 min, and absorbance was compared with the Trolox standard curve to express the values in µmol TE/ 100 g db. The wavelength used was 517 nm, and the solution was blanked to air.

Sensory Evaluation

Based on preliminary sensory characteristics, the DOF condition at 200 °C and 70 s and MWR for 50 s at the power level of 75 prepared in duplicates for evaluation. The sensory evaluation was carried out in random sessions evaluating 10 samples in each session (5 samples of DOF extrudate and the other 5 samples were of MWR samples).

For sensory evaluations, 10 untrained panelists (five male and five female with age between 20 and 35 years) were from chosen to carryout quality rating tests on a 7-point scale (1 = very bad, 2 = bad, 3 = below fair-above bad, 4 = fair, 5 = below good- above fair, 6 = good, 7 = very good) [22]. The measured characteristics of tests were color, crispiness, oiliness and overall acceptability [23].

Correlation coefficient (r)

Obtained physical and sensorial properties were analyzed based on statistical methods that involve Pearson's correlation coefficient analysis (r) which represents the linear degree relationship between two variables (Equation 3), [24].

$$r = \frac{\sum \left(\mathrm{A_i} - \overline{\mathrm{A}}\right)\left(\mathrm{B_i} - \overline{\mathrm{B}}\right)}{\sqrt{\sum \left(\mathrm{A_i} - \overline{\mathrm{A}}\right)^2 \sum \left(\mathrm{B_i} - \overline{\mathrm{B}}\right)^2}} \qquad (3)$$

where A and B are measured inputs, and $\mathrm{A}^{-}$and B^{-} are their mean values, respectively. The value of r for a sample is constrained as follows $-1 \leq \mathrm{r} \leq 1$.

3. Results and discussion

3.1 Expansion ratio (ER)

As shown in Table 2, the extrudate expansion ratio ranged from 1.97 to 2.21 and 2.06 to 2.45 for DOF and MWR, respectively. As can be further seen from the contour plots in Figure 1, the ER increased after frying, which could result from starch gelatinization, rapid moisture evaporation of the residual moisture or influx of oil [25–27]. Several studies have suggested that the ER of a product is influenced by the degree of starch gelatinization for extrusion cooking and direct heating [17–19]. However, as in pulse flour, protein and fiber could reduce the starch gelatinization and expansion of the product [28, 29]. Overall, the ER obtained from the MWR extrudates was higher than that of DOF. Hence, the microwave roasting process was able to give extrudates with higher puffiness and a more porous structure. The increase in the ER of the extrudates with microwave roasting was higher because, during processing, the expansion occurs throughout the whole structure (inside out concept) of extrudate compared to frying, which induced significant effects in the outer parts of the extrudate.

The RR, ER, and color data were used to evaluate the application of RF, GL, CP, and TP in both fried and microwave roasted products. The analysis of variance is shown in Table 3. Overall, the data showed color interaction effects of TP with RF, GL, and CP significantly different in fried samples. A similar interaction was not evident in MWR samples. In contrast, TP's textural interaction with RF, GL, and CP was significant for MWR samples. Different RF application interactions can be seen in Table 3; the ER of the DOF products was also significantly affected ($p<0.01$) by the proportion of RF, GL and CP. The interaction effect of RF-TP, GL-TP, and CP-TP also significantly affected the expansion of extrudate. The expansion ratio of extrudates was affected the most by incorporating CP with a decrease in expansion ratio with an increasing CP. However, the frying improved the ER as compared to just extrusion air-dried extrudate.

3.2 Breaking stress (BS)

Breaking stress was directly related to the product's hardness, as increased hardness leads to an increase in the force required to break the product. The minimum and maximum values calculated for extrudate BS ranged between 0.23 to 0.47 and 0.13 to 0.31 (N/mm^2) for DOF and MWR samples, respectively (Table 2). An increase in BS reduces the product's acceptability as the product because higher hardness makes it harder to bite. Generally, the hardness of 200 N is considered undesirable [30].

As shown in Figure 1, the BS decreased with the increasing RF content, whereas the increment of GL and TP increased the hardness, simultaneously increasing the value for BS. The correlation factor between ER and BS was observed to be negative ($r = -0.87$), suggesting that increasing ER reduces BS due to the weakening properties of air cell when present in the product [31]. Hence, DOF helped in producing a product with lower BS by increasing air cell size.

With MWR samples, the linear regression equation's coefficients were related positively to the value of BS (Table 4). From the contour graph shown in Figure 1, it was observed that BS increased with increasing GL in the formulation, whereas increasing RF decreased the force required to bring a break in the extrudate. Lentils are rich in proteins. Thus, compared to starch, lentils can form stronger molecular bonds to increase hardness.

3.3 Rehydration Ratio (RR)

RR value for DOF ranged from 93.21 to 150.25 (Table 2) and was significantly affected ($p<0.01$) by the proportion of all independent variables as well the interaction effect of R-TP and C-TP (Table 3). The contour graph (Figure 1) shows the effect of individual product variables on the RR. It was observed that the value of the RR was higher in the products with higher expansion because of the formation of air cells.

RR value of the MWR products ranged from 157 to 257 (Table 2). The increase in RR is mainly because of the high ER achieved in extrudates. As expansion was observed throughout the matrix, many air cells were available for water to enter, increasing the rehydration ratio of the product. The effect of variables used on the RR is shown in Figure 1 through a/the contour graph. The contour graph indicated that a high RR was observed with increasing RF proportion. The rehydration ratio was observed above 200 with an RF content of above 45%. The relatively lower RR in DOF samples could also be due to this component's oil intake and hydrophobicity within the fried tissue.

3.4 Color

The L* value ranged from 9.01 as the minimum value to 17.9 as the maximum value. The L*, a*, and b* values of both products were significantly affected ($p<0.01$) by the proportion of RF, GL, and the interaction effect of RF and CP. It can be observed from the contour graph (Figure 2) that increasing PF decreased the value of L*, and higher RF content in formulation resulted in higher L* values. This is because the high protein content in pulse flour increased lysine availability, which can readily react with reducing sugars and lead to non-enzymatic browning. Similar results and trends were also observed in developing protein-rich extrudates by [30]. The value of L* was also affected by increasing a* values ($r = -0.77$). A similar trend was found in Altan *et al.* [32] in their respective studies. The value of L* ranged from 19.2 to 29.6 for MWR products. In this regard, higher L*

Table 2 Responses obtained for physical characteristics of fried and microwave roasted extrudates

	Run	ES	L*	a*	b*	BS	RR	AA
Fried	1	1.98±0.09	9.94±2.57	9.02±0.53	-1.38±1.14	0.42±0.05	102±3	45.38±2.67
	2	2.07±0.05	15.3±3.98	7.73±0.57	2.73±1.09	0.26±0.06	150±4	28.32±3.89
	3	2.07±0.06	11.36±3.09	8.83±0.62	1.97±1.43	0.32±0.04	114±5	26.72±2.51
	4	2.21±0.05	17.89±4.98	7.27±0.57	2.56±1.00	0.23±0.05	149±4	34.39±3.09
	5	2.07±0.05	10.94±2.95	8.69±0.79	0.78±0.43	0.37±0.06	111±3	31.83±1.49
	6	2.01±0.05	9.47±2.09	8.63±0.48	-1.46±0.95	0.38±0.07	98±5	33.91±2.59
	7	1.97±0.06	10.27±2.78	8.27±0.28	-2.35±0.34	0.42±0.03	95±4	52.47±3.01
	8	2±0.04	9.72±1.97	8.74±0.56	-0.73±0.45	0.47±0.05	101±4	55.12±3.98
	9	2.09±0.05	13.36±4.09	8.21±0.87	1.8±1.09	0.29±0.06	150±4	37.38±3.51
	10	2.1±0.03	14.51±4.87	7.63±0.23	2.88±1.08	0.28±0.05	135±5	38.62±2.91
	11	2.04±0.10	11.91±2.98	8.96±0.54	0.85±1.09	0.36±0.04	118±5	45.73±4.15
	12	2.08±0.11	13.47±3.09	7.89±0.64	2.78±0.34	0.27±0.05	136±5	24.82±3.17
	13	2.11±0.09	16.83±4.69	8.26±0.53	2.02±1.01	0.23±0.06	145±5	43.84±3.18
	14	2.1±0.06	14.72±5.67	8.34±0.87	4.34±2.09	0.25±0.04	142±7	26.78±3.71
	15	2.14±0.06	16.04±5.20	7.92±0.75	5.16±2.09	0.23±0.03	146±6	46.38±4.59
	16	1.98±0.04	10.35±2.93	8.23±0.54	-2.18±0.98	0.41±0.04	93±6	31.57±3.78
	17	2.01±0.06	9.01±2.76	8.94±0.75	-1.72±0.88	0.38±0.03	97±7	41.63±3.09
	18	2.03±0.05	14.09±3.89	8.39±0.24	1.09±0.76	0.34±0.05	132±5	53.82±3.89
	19	2.07±0.06	13.52±3.09	8.35±0.65	-1.66±1.09	0.37±0.05	113±8	44.95±1.75
	20	2.13±0.06	14.73±5.87	8.17±0.45	2.32±1.21	0.28±0.06	142±5	24.81±0.78
Micro-wave Roasted	1	2.17 ±0.07	22.18± 1.15	8.91±0.39	13.34±1.98	0.28±0.04	161±2	67.79±2.78
	2	2.23 ± 0.05	26.87±2.07	7.65±0.67	12.05± 1.31	0.27±0.06	211±3	49.47±1.17
	3	2.19 ±0.07	24.21±1.98	8.31±0.71	13.41±0.45	0.21±0.04	202±3	47.61±1.91
	4	2.31 ±0.08	29.57±3.11	5.87±0.45	12.81±2.23	0.13±0.05	222±2	53.75±3.59
	5	2.23 ±0.05	22.68±1.90	8.34±0.78	13.09±1.45	0.28±0.04	202±4	60.83±3.01
	6	2.18 ±0.11	22.17±1.55	8.87±0.59	13.24±1.96	0.31±0.06	187±5	56.92±2.98
	7	2.12 ±0.03	19.94±1.07	8.54±0.40	12.91±2.08	0.29±0.07	157±6	89.12±1.03
	8	2.06 ±0.06	19.2±1.49	8.35±0.61	13.17±0.92	0.3±0.05	172±4	91.29±4.74
	9	2.17 ±0.5	25.86±2.34	8.21±0.56	11.54±1.48	0.23±0.03	199±5	65.42±3.90
	10	2.38 ±0.07	28.86±3.98	7.25±0.49	11.02±2.8	0.19±0.08	234±4	67.31±5.17
	11	2.23 ±0.10	24.23±3.40	7.94±0.61	11.86±0.84	0.21±0.06	209±4	79.01±2.87
	12	2.26 ±0.06	27.81±4.01	7.25±0.47	11.64±2.90	0.21±0.10	257±4	37.82±4.72
	13	2.29 ±0.06	26.76±3.31	7.51±0.54	12.21±1.31	0.19±0.11	231±3	74.74±0.94
	14	2.28 ±0.07	26.91±3.72	6.85±0.46	11.53±2.23	0.24±0.06	230±6	38.77±4.05
	15	2.45 ±0.08	27.35±4.06	6.75±0.38	11.68±1.43	0.17±0.03	243±7	76.81±3.96
	16	2.14 ±0.07	21.03±4.48	8.38±0.65	13.01±1.97	0.3±0.02	197±8	54.29±2.87
	17	2.18 ±0.04	23.13±1.99	8.45±0.56	13.16±2.09	0.3±0.05	174±5	66.29±2.93
	18	2.21 ±0.07	25.31±3.59	7.97±0.37	11.99±0.55	0.27±0.04	213±5	85.39±1.17
	19	2.15 ±0.05	22.68±3.71	8.21±0.64	11.87±1.56	0.29±0.06	184±5	77.92±1.74
	20	2.27 ±0.11	28.76±3.37	7.1±0.37	13.26±1.33	0.24±0.11	219±5	35.68±3.52

Note: Level of salt and water added was identical for each run; 6 g of salt and 94 g of water was added to each batch of 400 g. ES= Expansion ratio, L*, a* and b* are color parameters, BS is breaking strength (N/mm2), RR = Rehydration ratio, AA is ascorbic acid content (μmol TE/ 100 g db).

Table 3 Responses obtained for physical characteristics of fried and microwave roasted extrudates

Source	L*	a*	b*	RR	ER	Hardness
Fried						
Model	< 0.0001	0.0012	< 0.0001	< 0.0001	0.0003	< 0.0001
Linear	< 0.0001	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Mixture						
AB	0.6721	0.0378		0.0549	0.1497	
AC	0.0067	0.0730		0.0129	0.3339	
AD	0.0564	0.0919		0.1606	0.0117	
BC	0.4485	0.2697		0.2001	0.4215	
BD	0.0866	0.0882		0.1598	0.0163	
CD	0.0587	0.1045		0.1952	0.0271	
Microwave roasted						
Model	< 0.0001	0.0001	< 0.0001	< 0.0001	0.0003	< 0.0001
Linear	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Mixture						
AD		0.3894	0.2448	0.0085	0.8439	
BC		0.7805	0.0982	0.4123	0.9753	
BD		0.2535	0.0688	0.0038	0.5251	
CD		0.2337	0.2628	0.0116	0.4547	

Note: $p \leq 0.05$ - significant; A- RF; B- GL; C- CP; D- TP.

Table 4 Regression equations obtained for physical properties of extrudates post-processed by deep oil frying (DOF) or Microwave Roasting (MWR)

	Physical properties	Equations (Actual value)	Mean Square error
DOF	L*	L*= (0.1269 * R) + (0.16716 * L) – (0.800066 * C) – (7.36716 * TP) – (0.00184039 * R * L) + (0.0184855 * R * C) + (0.0853025 * R * TP) + (0.00514249 * L * C) + (0.0745433 * L * TP) + (0.0861325 * C * TP)	3.68
	a*	a*= (0.0362283 * R) + (0.0252934 * L) + (0.284703 * C) + (1.79467 * TP) + (0.00247933 * R * L) – (0.00267188 * R * C) - (0.0181051* R * TP) – (0.00187085* L * C) – (0.0182039 * L * TP) - (0.0177071 * C * TP)	0.57
	b*	b*= (0.114331 * R) – (0.0978701 * L) – (0.0421598 * C) - (0.0883463 * TP)	1.03
	Expansion ratio	ER= (0.0236958 * R) + (0.0261418 * L) + (0.0158931 * C) - (0.281194 * TP) – (0.000180876 * R * L) + (0.000151385 * R * -(0.00310678 * L * TP) + (0.00286771 * C * TP)	0.06
	Rehydration Ratio	RR= (0.225801 * R) – (1.69869 * L) – (4.74002 * C) – (39.2249 * TP) + (0.0709888 * R * L) + (0.126815 * R * C) + (0.46381 * R * TP) + (0.0692135 * L * C) + (0.461207 * L * TP) + (0.433769 * C * TP)	4.97
	Breaking Stress	BS= - (0.000245896 * R) + (0.00689417 * L) + (0.00477592 * C) + (0.00823958 * TP)	0.05
M	L*	L*= (0.394548 * R) + (0.0775806 * L) + (0.216131 * C) + (0.0544558 * TP)	2.81
	a*	a*= -(0.0413211 * R) - (0.029593 * L) + (0.171804 * C) + (1.43869 * TP) + (0.00489261 * R * L) - (0.000432804 * R * C) - (0.011237 * R * TP) + (0.00058949 * L * C) – (0.0150145 * L * TP) – (0.016162 * C * TP)	0.54
	b*	b*= (0.168397 * R) + (0.185963 * L) – (0.0222306 * C) - (1.46728 * TP) –(0.00349467 * R * L) + (0.00229621 * R * C) + (0.0135696 * R * TP) + (0.00330117 * L * C) + (0.0222078 * L * TP) + (0.0133043 * C * TP)	1.64
	Expansion ratio	ER= (0.029064 * R) + (0.0204972 * L) + (0.030622 * C) + (0.0890001 * TP) –(0.000134554 * R * L) – (0.000268175 * R * C) + (0.000326483 * R * TP) + (8.44943e-006 * L * C) – (0.00105524 * L * TP) + (0.00128291 * C * TP)	0.09
	Rehydration Ratio	RR= (2.15925 * R) – (0.059789 * L) – (1.86193 * C) + (132.369 * TP) + (0.0453131 * R * L) + (0.0564364 * R * C) – (1.35375 * R * TP) + (0.0584818 * L * C) – (1.544 * L * TP) – (1.30444 * C * TP)	4.38
	Breaking Stress	BS= 0.00048127 * R + 0.00529262 * L + 0.00277038 * C + 0.000645885 * TP	0.06

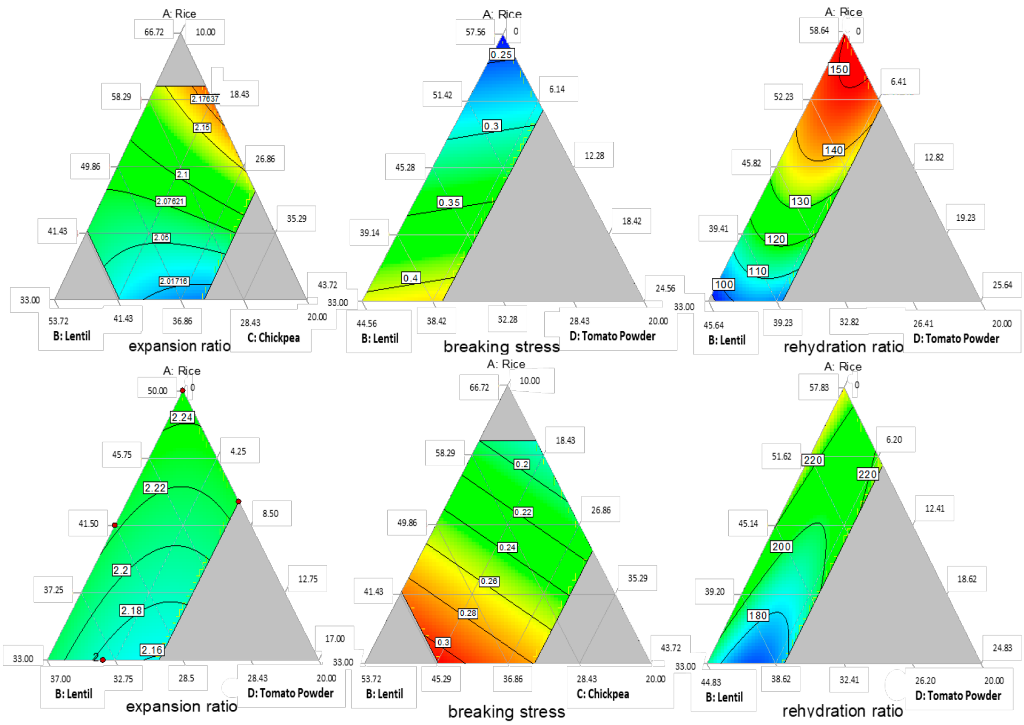

Figure 1 Effect of mixture formulation on expansion ratio (ER) at CP level of 30%, breaking stress (BS) at TP level of 3.5%, and (RR) when CP was 20% in the proportion. The Upper and lower row of contours belong to Fried, and Microwave roasted extrudates, respectively

values were observed with higher RF along with higher proportions of CP (Figure 2). The obtained data for a* values ranging from 7.27 to 9.02 and 5.87 to 8.91 for DOF and MWR suggest high redness because of TP inclusion in extrudates. However, Figure 2 indicates that increasing the CP's proportion in extrudates also increased the a* value. This can be because yellow and red colors complement each other for brightness, and increasing CP is intensifying the redness of extrudate. A similar trend was also reported by several researchers [32, 33].

Regarding the b* values increasing CP imparted a more yellowish color to the extrudate. Bright yellow color in extrudate is a desired attribute. Chickpea has a yellowish color of its own, and its increasing proportion in formulation produced snacks with higher yellowness.

3.5 Antioxidant activity (AA)

Antioxidant activity ranged from 35.7 to 91.3 μmol TE/ 100 g db in MWR extrudates and 24.8 to 55.1 μmol TE/ 100 g db for DOF extrudates. The highest antioxidant activity was observed in Run 8, and the lowest in Run 20 for both the processing methods (Table 2). As compared to DOF, which retained only 50%-55% of the extrudates, MWR retained more than 80% of the total antioxidants. The difference in time-temperature for both processing methods plays a significant role in the retention of antioxidant properties. Lycopene from TP is a major antioxidant source in the studied product. Mayeaux *et al.* [34] mentioned that even processing tomato slurry for 1 min at 100% power MWR retained more than 64% of the lycopene, whereas frying even at the lower temperature of 145□ C retained only 36.6% of the total lycopene. The high frying temperature of oil devalues antioxidants as oil can produce hydroperoxide free radicals and then increase the oxidation process, reducing antioxidants [35].

3.6 Sensory evaluation

The quality rating test is a broad category of rating methods used mainly for sensory evaluations with a smaller number of trained panelists. The success of a snack depends on its acceptance by the consumer. Even with better nutrition provided to snacks, the desirability of a snack is driven by its organoleptic properties. For an extruded or expanded product, these properties largely depend on the number and the size of the air cells [36]. Descriptive statistics can draw a relationship between sensory and intended properties being measured.

The results obtained from the sensory evaluation (scores are not shown) of the extrudates showed that all others were in an acceptable range except for one of the MWR

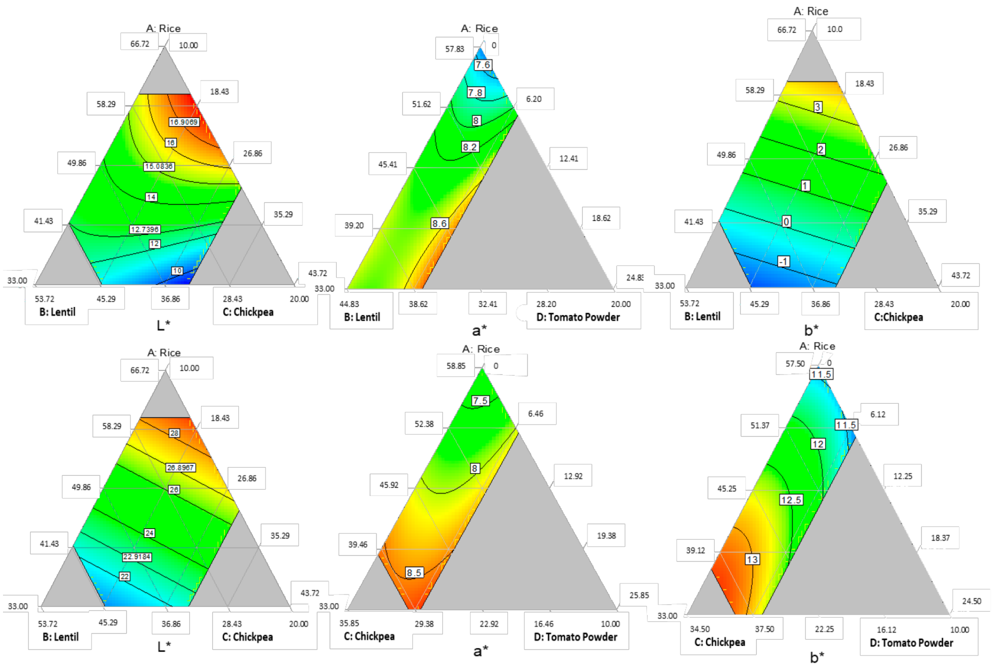

Figure 2 Contour graph for L*, a*, and b* values of Fried (upper row) and microwave roasted (lower row) at CP proportion of 3.5

samples (Run 8). Three sample runs (Run 2, 13, and 15) from fried extrudates scored high overall acceptability (7) compared to other DOF samples. Although all three runs scored an overall acceptability score of 7, the sample runs had different scores for color, crispiness and oiliness to different formulations. A more significant number of MWR extrudates exhibited desirable properties than fried extrudates (run numbers 2, 9, 10, 13, and 20 scored 7 for overall acceptability).

According to Table 5, response variables such as L* value, expansion ratio and rehydration ratio of fried, and microwave roasted products showed a high degree of positive correlation with sensorial scores viz. color, crispiness, oiliness, and overall acceptability of the product. However, even though the rehydration ratio also showed a positive correlation with sensorial attributes, microwave roasted extrudates showed a rehydration ratio too high, resulting in the breaking apart of extrudates' structure the absorption of water. Almost all the microwave roasted products scored high for the extrudates' oiliness, with both L* value and expansion ratio showing a positive correlation for oiliness in extrudates compared to fried extrudates. Both ER and L* values negatively correlated with the oiliness of DOF products but a positive correlation with MWR products with no oil uptake, which confirms that the uptake of oil by the extrudates plays a significant role in decreasing the acceptability of extrudates. Although the b* value was low for fried products, an increase in b* value was observed with an increase in CP, especially for MWR products. Increasing breaking stress value was negatively correlated with sensory attributes of the processing methods, and hence reducing breaking stress produced extrudates with higher overall acceptability. It should be noted that sampling typically requires a more significant number of untrained panelists. In this study, semi-trained panelists consisting of food science students were used. Since they were not fully trained, the sensory results could be treated a bit more qualitative than fully quantitative. Nevertheless, they are good indicators of the performance of the flavor enhancement treatments.

4. Conclusions

The post extrusion DOF and MWR treatments of extrudate samples (dehydrated to an 18% db moisture content) helped to enhance the physical properties of the resulting product and sensorial attributes. The degrees of correlation between quality parameters measured instrumentally and sensory tests were observed to be strong. Rice-based extrudates incorporated with GL, CP and TP were roasted by MWR with no oil and without changing the overall acceptability of the product, thereby reducing the concerns of fat and calorie intake. DOF also resulted in an acceptable product, but with significant inclusion of the cooking oil. Among physical characteristics, ER had a strong positive correlation with overall acceptability. Breaking stress also had a significant negative correlation confirming higher desirability of products with higher ER.

Table 5 Analysis of correlation coefficient between physical properties and sensory evaluation of post-processed extrudates

Instrumental Response			Value of correlation r			
			Color	**Crispiness**	**Oiliness**	**Overall Acceptability**
Color	**L***	**DOF**	0.52	0.77	-0.15	0.81
		MWR	0.35	0.37	0.35	0.76
	a*	**DOF**	-0.40	-0.66	0.36	-0.59
		MWR	-0.34	-0.27	0.01	-0.49
	b*	**DOF**	0.57	0.84	-0.07	0.75
		MWR	0.24	-0.43	-0.35	-0.40
Rehydration ratio		**DOF**	0.48	0.86	-0.13	0.84
		MWR	0.31	0.53	0.40	0.51
Expansion ratio		**DOF**	0.57	0.74	-0.08	0.77
		MWR	0.43	0.35	0.34	0.60
Breaking stress		**DOF**	-0.67	-0.89	-0.01	-0.85
		MWR	-0.38	-0.08	-0.20	-0.52

Note: 'DOF' and 'MWR' are the abbreviations for deep oil fried extrudates or microwave roasted extrudates. The signs '+' refers to "positive" linear correlation (correlated variable will tend to increase), whereas sign '-' means the correlation between the variables is negative (correlated variable will tend to decrease). No linear correlation is denoted by a value of 0; The closeness of value to 1 or -1 indicates higher strength of linear correlation where 0.00-0.19 suggests "very weak" correlation; 0.20-0.39 suggests correlation is "weak"; 0.40-0.50 suggests the strength of the correlation is "moderate"; 0.60-0.79 suggests a "strong" correlation; 0.80-1.00 suggests a "very strong" correlation (source: [24]).

5. Declaration of competing interest

We declare that we have no competing interests, including financial or non-financial, professional, or personal interests interfering with the full and objective presentation of the work described in this manuscript.

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7. Author contributions

Author Prabhjot Singh carried out the work, analysed the results and prepared the manuscript draft, author Hamed Vatankhah assisted in planning and execution of the experiments, preparation of the manuscript draft and author Hosahalli Ramaswamy supervised the project, planning, execution of the project and final manuscript preparation.

8. Data Availability Statement

For the origin of the data, all necessary details are provided in the manuscript. Additional information will be provided up on request.

References

[1] R. C. Claws and *et al.*, "Continuous access to snacks from weaning onwards in female rats causes weight gain, insulin insensitivity, and sustained leptin resistance in adulthood," *Physiology & Behavior*, vol. 201, Mar. 2019. [Online]. Available: https://doi.org/10.1016/j.physbeh.2018.11.026

[2] C. de Graaf, "Effects of snacks on energy intake: An evolutionary perspective," *Appetite*, vol. 47, no. 1, Jul. 2006. [Online]. Available: https://doi.org/10.1016/j.appet.2006.02.007

[3] W. S. Hassen and *et al.*, "Energy, nutrient and food content of snacks in french adults," *Nutrition Journal*, vol. 17, no. 33, Feb. 27, 2018. [Online]. Available: https://doi.org/10.1186/s12937-018-0336-z

[4] N. K. Gill, "Process eqvaluation and quality optimization of apple snack," M.S. thesis, McGill University, Montreal, Canada, 2003.

[5] R. Sandrin, T. Caon, A. W. Zibetti, and A. de Francisco, "Effect of extrusion temperature and screw speed on properties of oat and rice flour extrudates," *Journal of the Science of Food and Agriculture*, vol. 98, no. 9, Jul. 2018. [Online]. Available: https://doi.org/10.1002/jsfa.8855

[6] A. Rodríguez-Vidal, "Extruded snacks from whole wheat supplemented with textured soy flour: Effect on instrumental and sensory textural characteristics," *Journal of Texture Studies*, vol. 48, no. 3, Jun. 2017. [Online]. Available: https://doi.org/10.1111/jtxs.12234

[7] E. Bekkering. (2014) Pulses in canada. Statistics Canada. Ottawa, CA. [Online]. Available: t.ly/3UgE

[8] P. Watts, "Global pulse industry: state of production, consumption and trade; marketing challenges and opportunities," in *Pulse foods: Processing, quality and nutraceutical applications*, 2011, pp. 437–464.

[9] J. W. Anderson, B. M. Smith, and C. S. Washnock, "Cardiovascular and renal benefits of dry bean and soybean intake," *The American Journal of Clinical Nutrition*, vol. 70, no. 6, Sep. 1999. [Online]. Available: https://doi.org/10.1093/ajcn/70.3.464s

[10] L. A. Bazzano and *et al.*, "Legume consumption and risk of coronary heart disease in us men and women nhanes i epidemiologic follow-up study," *Arch Intern Med*, vol. 161, no. 21, Nov. 2001.

[Online]. Available: https://doi.org/10.1001/archinte.161.21.2573

[11] A. N. Mudryj, "Pulse consumption: A global perspective," *Health Benefits of Pulses*, Apr. 2019. [Online]. Available: https://doi.org/10.1007/978-3-030-12763-3_2

[12] J. C. Mathers, "Pulses and carcinogenesis: Potential for the prevention of colon, breast and other cancerse," *British Journal of Nutrition*, vol. 88, no. S3, Mar. 2007. [Online]. Available: https://doi.org/10.1079/BJN2002717

[13] J. K. Pittaway, I. K. Robertson, and M. J. Ball, "Intake in an ad libitum diet, leading to small improvements in serum lipid profile and glycemic control," *Journal of the American Dietetic Association*, vol. 108, no. 6, Jun. 2008. [Online]. Available: https://doi.org/10.1016/j.jada.2008.03.009

[14] A. N. Mudryj and *et al.*, "Intake in an ad libitum diet, leading to small improvements in serum lipid profile and glycemic control," *Journal of the American Dietetic Association*, vol. 108, no. 6, Jun. 2008. [Online]. Available: https://doi.org/10.1016/j.jada.2008.03.009

[15] P. Bouchon and V. Dueik, "Friyng of foods," in *Fruit Preservation: Novel and Conventional Technologies*, A. Rosenthal, R. Deliza, J. Welti-Chanes, and G. V. Barbosa-Cánovas, Eds. New York, NY: Springer, 2018, pp. 275–309.

[16] F. Hashempour-Baltork, M. Torbati, S. Azadmard-Damirchi, and G. P. Savage, "Quality properties of puffed corn snacks incorporated with sesame seed powder," *Food Science & Nutrition*, vol. 6, no. 1, Jan. 2018. [Online]. Available: https://doi.org/10.1002/fsn3.532

[17] L. C. Oliveira, M. Schmiele, and C. J. Steel, "Development of whole grain wheat flour extruded cereal and process impacts on color, expansion, and dry and bowl-life texture," *LWT*, vol. 75, Jan. 2017. [Online]. Available: https://doi.org/10.1016/j.lwt.2016.08.064

[18] S. Kallu, R. J. Kowalski, and G. M. Ganjyal, "Impacts of cellulose fiber particle size and starch type on expansion during extrusion processing," *Journal of Food Science*, vol. 82, no. 7, Jan. 2017. [Online]. Available: https://doi.org/10.1111/1750-3841.13756

[19] F. H. Brishti and *et al.*, "Impacts of cellulose fiber particle size and starch type on expansion during extrusion processing," *Journal of Food Science*, vol. 82, no. 7, Jul. 2017. [Online]. Available: https://doi.org/10.1111/1750-3841.13756

[20] L. Yu, H. S. Ramaswamy, and J. Boye, "Twin-screw extrusion of corn flour and soy protein isolate (spi) blends: A response surface analysis," *Food and Bioprocess Technology*, vol. 5, Nov. 2009. [Online]. Available: https://doi.org/10.1007/s11947-009-0294-8

[21] I. Martínez-Valverde, M. J. Periago, G. Provan, and A. Chesson, "Phenolic compounds, lycopene and antioxidant activity in commercial varieties of tomato (*Lycopersicum esculentum*)," *Journal of the Science of Food and Agriculture*, vol. 82, no. 3, Feb. 2002. [Online]. Available: https://doi.org/10.1002/jsfa.1035

[22] M. M. B. de Souza, A. M. P. Santos, A. Converti, and M. I. S. Maciel, "Optimisation of umbu juice spray drying, and physicochemical, microbiological and sensory evaluation of atomised powder," *Journal of Microencapsulation*, vol. 37, no. 3, Jan. 29, 2020. [Online]. Available: https://doi.org/10.1080/02652048.2020.1720031

[23] S. A. Tadesse, G. Bultosa, and S. Abera, "Chemical and sensory quality of sorghum-based extruded product supplemented with defatted soy meal flour," *Cogent Food & Agriculture*, vol. 5, no. 1, Aug. 16, 2019. [Online]. Available: https://doi.org/10.1080/23311932.2019.1653617

[24] R. Taylor, "Interpretation of the correlation coefficient: A basic review," *Journal of Diagnostic Medical Sonography*, vol. 6, no. 1, Jan. 01, 1990. [Online]. Available: https://doi.org/10.1177/875647939000600106

[25] K. Suknark, R. D. Phillip, and Y. W. Huang, "Tapioca-fish and tapioca-peanut snacks by twin-screw extrusion and deep-fat frying," *Journal of Food Science*, vol. 64, no. 2, Mar. 1999. [Online]. Available: https://doi.org/10.1177/875647939000600106

[26] C. H. Kuo, C. J. Shieh, S. M. Huang, H. M. D. Wang, and C. Y. Huang, "The effect of extrusion puffing on the physicochemical properties of brown rice used for saccharification and chinese rice wine fermentation," *Food Hydrocolloids*, vol. 94, Sep. 2019. [Online]. Available: https://doi.org/10.1016/j.foodhyd.2019.03.040

[27] J. Maneerot, A. Noomhorm, and P. S. Takhar, "Optimization of processing conditions to reduce oil uptake and enhance physico-chemical properties of deep fried rice crackers," *LWT - Food Science and Technology*, vol. 42, no. 4, May. 2019. [Online]. Available: https://doi.org/10.1016/j.lwt.2008.11.012

[28] J. Ye and *et al.*, "Properties of starch after extrusion: A review," *Starch*, vol. 70, no. 11-12, Nov. 2018. [Online]. Available: https://doi.org/10.1002/star.201700110

[29] C. I. Onwulata, P. W. Smith, R. P. Konstance, and V. H. Holsinger, "Incorporation of whey products in extruded corn, potato or rice snacks," *Food Research International*, vol. 34, no. 8, 2001. [Online]. Available: https://doi.org/10.1016/S0963-9969(01)00088-6

[30] S. F. Forsido and H. S. Ramaswamy, "Protein rich extruded products from tef, corn and soy protein isolate blends," *Ethiopian Journal of Applied Sciences and Technology*, vol. 2, no. 2, Dec. 23, 2011. [Online]. Available: https://api.semanticscholar.org/CorpusID:136041329

[31] A. H. Barrett and M. Peleg, "Extrudate cell structure-texture relationships," *Journal of Food Science*, vol. 57, no. 5, Sep. 1992. [Online]. Available: https://doi.org/10.1111/j.1365-2621.1992.tb11311.x

[32] A. Altan, K. L. McCarthy, and M. Maskan, "Evaluation of snack foods from barley–tomato pomace blends by extrusion processing," *Journal of Food Engineering*, vol. 84, no. 2, Jan. 2008. [Online]. Available: https://doi.org/10.1016/j.jfoodeng.2007.05.014

[33] Z. Dehghan-Shoar, A. K. Hardacre, and C. S. Brennan, "The physico-chemical characteristics of extruded snacks enriched with tomato lycopene," *Food Chemistry*, vol. 123, no. 4, Dec. 15, 2010. [Online]. Available: https://doi.org/10.1016/j.foodchem.2010.05.071

[34] M. Mayeaux, Z. Xu, J. M. King, and W. Prinyawiwatkul, "Effects of cooking conditions on the lycopene content in tomatoes," *Journal of Food Science*, vol. 71, no. 8, Oct. 2006. [Online]. Available: https://doi.org/10.1111/j.1750-3841.2006.00163.x

[35] E. K. Oke, M. A. Idowu, O. P. Sobukola, S. A. O. Adeyeye, and A. O. Akinsola, "Frying of food: A critical review," *Journal of Culinary Science & Technology*, vol. 16, no. 2, Apr. 2018. [Online]. Available: https://doi.org/10.1080/15428052.2017.1333936

[36] N. E. Morsy, A. M. Rayan, and K. M. Youssef, "Physico chemical properties, antioxidant activity, phytochemicals and sensory evaluation of rice-based extrudates containing dried *Corchorus olitorius* l. leaves," *Food Processing & Technology*, vol. 6, no. 1, 2015. [Online]. Available: https://doi.org/10.4172/2157-7110.1000408