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Sensory, Physico-Chemical, Microbial and Textural Changes in Ragi and Milk Solids Based Extruded Snack Food during Storage

Arunkumar[1], Amitkumar Manojbhai Patel[2], Niranjan[3*] and Smitha Balakrishnan[2]

[1]*Amul Dairy, Mumbai India*
[2]*SMC College of Dairy Science Anand, Kamdhenu University Gandhinagar, Gujarat, India*
[3]*Manmul Cooperative Mandya Karnataka, India*

**Corresponding author*

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The increasing demand for the healthy snack foods has been growing over the past five years. Cereals play a crucial role in human diet and nutrition. The protein quality of cereals can be enhanced by combining it with other rich sources of protein. Whey-based components have attracted a considerable attention in recent years owing to their potential as functional food ingredient as well as nutritional supplements. Whey protein is the best source for milk protein fortification in junk foods.The ragi and milk solids based extruded snack food and control samples were stored at 37±2°C after packaging in MET PET. Changes in physico-chemical, sensory and textural properties were analyzed along with microbiological quality at 10-day intervals.Sensory scores, fracturability for experimental sample and control decreased while moisture, water activity and hardness increased during entire storage period. Standard plate count decreased, while coliform count and yeast and mold count were not detected up to 120 days of storage.

Introduction

Snacks are foods eaten between meals to satisfy hunger. Many snack foods are produced by manufacturers, with extruded products being especially popular. Snack food consumption has significantly increased over the past 25 years due to its convenience and affordability. This trend is observed across all age groups, including adolescents and children. (Sebastian *et al.,* 2008). The snack industry is under pressure to make healthier products. In India, there are over 1,000 different types of snacks and 300 types of savories (Conti-Silva *et al.*, 2012; Brennan *et al.*, 2013). Extrusion cooking is a versatile and efficient method used in producing breakfast cereals, snack foods, and baby food (Huber, 2001). Snacks often contain cereals, vegetable proteins, and starch to provide texture, structure, mouthfeel, and bulk density. (Launay and Lisch, 1983; Tahnoven *et al.*, 1998). Patel and Verma (2013) found that ragi (finger millet) can be used to create nutritious value-added food products. Ragi is a rich source of calcium (344 mg per 100g), making it ideal for children, expectant mothers, and the elderly. It is also a suitable food for diabetics due to its slow sugar release and high fiber content, which helps prevent constipation, high blood cholesterol, and intestinal cancer. Extrusion cooking is a modern processing technology that uses high pressure, shear forces, and mixing to produce an extrudate with unique properties (Zheng and Wang, 1994). This is achieved through protein denaturation, starch gluten formation and plasticization of the raw materials, which expands through the die due to abrupt pressure drop. Extrusion cooking relies on several factors, such as feed ingredients, feed moisture, screw speed, barrel temperature, and feed ratio, to determine the quality of the final product (Cai *et al.*, 1995). The aim of this study was to evaluate the Sensory, physico-chemical, microbial, and textural changes in ragi and milk based extruded snack food.

Materials and Methods

Raw Materials

Good quality corn, rice and ragi flour was procured from local market of Anand. Whey protein concentrate (WPC) containing 80% protein (WPC-80) was purchased from Arla Foods Pvt. Ltd. Commercially available good quality crystal iodised salt (TATA brand) was procured from local market and used in the study.

Equipment / Instruments

The equipment and instruments used in the present study are detailed below

Equipment used in the present study included hot air oven (Model No. IK-III, IKON, India), analytical balance (Sartorius, England), vortex mixture (SAIF Surgical and Scientific Equipment, Gujarat), Kjeldahl protein estimation unit (Model- KPS 006L, Kjel-Plus digestion and distillation units, M/s. Pelican Instruments, Chennai, India), muffle furnace (Model No. EIE-500 (5kW), Erection and Instrumentation Engineers, Ahmedabad, India), water activity meter (Hygrolab 3, Rotronic Measurement Solutions AG, Switzerland), texture analyser (Stable Micro Systems, UK), co-rotating twin screw extruder (BTPL lab model, Basic Technology Pvt. Ltd. Kolkata, India).

Glasswares

All glasswares used in the study were of standard quality supplied by authorized dealers. In case of specific experiments, the calibrated glasswares as specified by Bureau of Indian Standards (BIS, 1981) were used.

Chemicals

All the chemicals used in the preparation of different reagents were of analytical grade (AR) and were procured from standard companies. The reagents required for analysis were freshly prepared adopting standard procedures.

Packaging Materials

Extruded snack after drying was packed in metallized polyethylene terephthalate (MET PET) pouches of 12 microns thickness and the pouches were stored at 37±2°C.

Manufacture of Ragi and Milk based Extruded Snack Food

Preliminary trails were carried out for selection of various ingredients like corn flour, rice flour, ragi flour, whey protein concentrates, whey and salt. Initially, trials were conducted for standardizing the levels of ragi flour, corn flour, whey protein concentrates in combination with rice. Based on preliminary trials, total flour weight (100 g) consisted ragi flour, corn flour, rice flour and whey protein concentrates. In that rice flour will be added by difference so that the final formulation of composite flour becomes 100 per cent. Water was added at the rate of 10 percent of total flour weight and its concentration was kept constant. WPC-80 was added at the rate of 5-10 percent of total flour weight.

Salt at the level of 2 percent of the flour weight was incorporated in to the flour mixture. The composite flour mixture was sieved and then filled in low density polyethylene (LDPE) pouches and kept for preconditioning at room temperature for 2 h. The extrusion cooking parameters were as follows - barrel temperature: 110°C, extruder rpm: 330, feeder rpm: 15, cutter rpm: 160 (based on preliminary trials).

Results and Discussion

The Ragi and milk based extruded snack food T2 and control sample T1 were stored at 37±2°C after packaging in MET PET material. Samples were analyzed for changes in sensory, physico-chemical, textural characteristics, and microbiological quality at 10-day intervals.

Changes in the Sensory Characteristics of Ragi and Milk Based Extruded Snack Food during Storage

The changes in sensory characteristics of samples T1 and T2 packed in MET PET and stored at room temperature (37±2ºC) is shown in the Table 1. The flavour, colour and appearance, texture, volume expansion and overall acceptability scores of T1 and T2 decreased at the end of 120 days of storage at room temperature (37±2ºC).

The changes in the flavour, colour and appearance, texture, volume expansion and overall acceptability scores of the treatments (T1 and T2) and interaction effect between the treatments and periods were significant (P<0.05). This shows that there was significant (P<0.05) effect of change in formulation on storage stability of product with respect to flavour, colour and appearance, texture, volume expansion and overall acceptability characteristics. The flavour scores of control extruded food T1 decreased below 7.0 (which stands for like moderately on 9-point hedonic scale) after 110 days of storage while that of WPC based extruded food T2 decreased below 7.0 after 100 days of storage at 37±2ºC. But the flavour score of both the T1 and T2 were less than 6.0 (which stands for like slightly on 9-point hedonic scale) on 120th day of storage.

The colour and appearance score and texture score of both T2 and T1 decreased below 6.0 (which stands for like slightly on 9-point hedonic scale) after 120 days of storage at 37±2ºC.

The changes in the scores of volume expansion shows that there was significant (P<0.05) effect of change in formulation (incorporation of WPC-80) on storage stability of product.

The volume expansion scores of control extruded food T1 decreased below 6.0 (which stands for like slightly on 9-point hedonic scale) after 120 days of storage while that ragi and milk based extruded snack food T2 decreased almost 6.0 after 120 days of storage at 37±2 ºC. The overall acceptability scores of control extruded food T1 decreased below 6.0 (which stands for like slightly on 9-point hedonic scale) after 120 days of storage while that of ragi and milk based extruded snack food T2 decreased below 6.0 after 120 days of storage at 37±2ºC.

The overall acceptability score of milk solids based extruded snack food T2 was below 6.0 on 120th day of storage at 37±2ºC, so the storage study was discontinued after 120 days. Based on sensory evaluation it was concluded that whey protein concentrate based extruded snack food T2 packaged in MET PET was acceptable up to 120 days of storage at 37±2ºC.

Raja *et al.,* (2014) observed that the initial average score for flavour, appearance, texture, crispiness and overall acceptability characteristics the extruded fish curls sample decreased after 28 days at ambient storage. Ali *et al.,* (2016) observed that the initial average score for taste, color, crispiness, chewiness, pore distributions, surface characteristics and overall acceptability of the extruded products prepared from corn grits – corn starch with common carp fish decreased after 3 months at ambient storage.

Singh *et al.,* (2017) reported that the initial score for flavour, appearance, texture and overall acceptability characteristics of corn and chickpea based extruded food decreased after 3 months during storage at ambient temperature.

Mehta (2016) found that the average score for flavour, color and appearance, texture and overall acceptability of the extruded corn based sample were decreased after 90 days at ambient storage.

Changes in the Physico-Chemical Characteristics of Ragi and Milk Solids Based Extruded Snack Food during Storage

The moisture content of T_1 and T_2 increased from 3.67 and 3.41 per cent on zero day to 5.15 and 5.02 per cent respectively at the end of 120 days of storage at room temperature (37±2ºC) as shown in Table 2.

The interaction effect between the treatments and periods were significant ($P<0.05$) for changes in moisture content. The increase in moisture content was due to hygroscopic nature of extrudates (Butt *et al.,* 2004).

The water activity of T_1 and T_2 increased from 0.334 and 0.329 on zero day to 0.496 and 0.493 respectively at the end of 120 days of storage at room temperature (37±2ºC). The changes in the water activity among the treatments T_1 and T_2 and the interaction effect between the treatments (T_1 and T_2) and periods were significant ($P<0.05$).

This shows that there is significant effect of change in formulation on storage stability of product with respect to water activity. The slight increase of water activity in extrudates was possibly due to the change in humidity of the surrounding environment (Nissar *et al.,* 2017). Charunuch *et al.,* (2008) reported increase in moisture content in Thai rice extruded snack supplemented with mulberry from 3.5 to 5 % during storage of 4 months.

Pawar *et al.,* (2012) observed that moisture and water activity content of egg based snack food increased gradually from the initial value of 2.07 to 2.75 and 0.25 to 0.34 respectively, when stored for 6 months at ambient temperature. Increase in water activity during storage could be because of increase in moisture content.

Sharma *et al.,* (2015) observed that the initial average water activity and moisture of the millet-cowpea extruded snacks samples increased from 0.49 and 5.9 per cent and to 0.60 and 8.8 per cent respectively after 4 months of storage at ambient storage.

Nissar *et al.,* (2017) observed that the initial average water activity and moisture of the corn based breakfast snacks samples increased from 0.42 and 3.36 per cent to 0.53 and 4.68 per cent after 90 days at ambient storage.

Changes in the Textural Characteristics of Ragi and Milk Solids Based Extruded Snack Food during Storage

The changes in textural characteristics of ragi and milk solids based extruded snack food and control during storage is shown in Table 3. The hardness of T_1 and T_2 increased from 4.87 and 4.15 N on zero day to 11.23 and 10.51 N respectively at the end of 120 days of storage at room temperature (37±2ºC).

The changes in the hardness among the treatments T_1 and T_2 and the interaction effect between the treatments and periods were significant ($P<0.05$).

Increase in hardness during storage could be due to increase in the moisture content of extrudates as shown in Table 3 resulting in an increase in the starch bonding.

Table.1 Influence of storage period on sensory characteristics extruded snack food

Types of extruded food	Storage period (days)													Average (treatments)
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	
Flavour score														
T_1	**7.86**	**7.77**	**7.73**	**7.69**	**7.68**	**7.35**	**7.16**	**7.13**	**7.07**	**6.90**	**6.70**	**6.60**	**5.88**	**7.19**
T_2	**8.36**	**8.32**	**8.26**	**8.25**	**8.19**	**8.09**	**7.90**	**7.80**	**7.64**	**7.48**	**7.26**	**6.47**	**5.99**	**7.69**
Average of periods	**8.11**	**8.04**	**8.00**	**7.98**	**7.93**	**7.72**	**7.53**	**7.47**	**7.36**	**7.19**	**6.98**	**6.54**	**5.94**	
CD(0.05) T = 0.02; P = 0.07; T×P = 0.10; CV% = 0.85														
Colour & appearance score														
T_1	**8.26**	**8.19**	**7.88**	**7.79**	**7.63**	**7.36**	**7.23**	**6.97**	**6.91**	**6.89**	**6.71**	**6.20**	**5.85**	**7.22**
T_2	**8.36**	**8.31**	**8.20**	**8.06**	**8.02**	**7.86**	**7.71**	**7.55**	**7.40**	**7.15**	**6.60**	**6.11**	**5.94**	**7.48**
Average of periods	**8.31**	**8.25**	**8.04**	**7.93**	**7.82**	**7.61**	**7.47**	**7.26**	**7.14**	**7.03**	**6.65**	**6.15**	**5.90**	
CD(0.05) T = 0.02; P = 0.05; T×P = 0.07.; CV% = 0.61														
Texture score														
T_1	**7.75**	**7.65**	**7.53**	**7.47**	**7.41**	**7.37**	**7.23**	**6.97**	**6.89**	**6.91**	**6.72**	**6.20**	**5.84**	**7.07**
T_2	**8.18**	**8.14**	**7.99**	**7.75**	**7.65**	**7.62**	**7.55**	**7.30**	**7.02**	**6.92**	**6.72**	**6.55**	**5.94**	**7.33**
Average of periods	**7.97**	**7.89**	**7.77**	**7.61**	**7.53**	**7.47**	**7.43**	**7.13**	**6.95**	**6.92**	**6.72**	**6.37**	**5.89**	
CD(0.05) T = 0.02; P = 0.07; T×P = 0.9; CV% = 0.78														
Volume expansion score														
T_1	**8.39**	**8.35**	**8.26**	**8.10**	**7.85**	**7.82**	**7.67**	**7.46**	**7.33**	**7.06**	**6.75**	**6.46**	**5.98**	**7.50**
T_2	**8.32**	**8.21**	**8.13**	**8.04**	**7.94**	**7.85**	**7.80**	**7.74**	**7.50**	**7.27**	**7.12**	**6.85**	**6.15**	**7.61**
Average of periods	**8.35**	**8.28**	**8.19**	**8.07**	**7.90**	**7.84**	**7.73**	**7.60**	**7.41**	**7.17**	**6.93**	**6.65**	**6.06**	
CD(0.05) T = 0.03; P = 0.07; T×P = 0.10; CV% =0.81														
Overall acceptability score														
T_1	**7.90**	**7.80**	**7.66**	**7.58**	**7.50**	**7.35**	**7.14**	**6.96**	**6.72**	**6.52**	**6.28**	**6.10**	**5.98**	**7.04**
T_2	**8.31**	**8.20**	**8.13**	**8.04**	**7.93**	**7.82**	**7.65**	**7.48**	**7.21**	**6.95**	**6.57**	**6.22**	**5.99**	**7.43**
Average of periods	**8.10**	**8.00**	**7.89**	**7.81**	**7.71**	**7.58**	**7.39**	**7.22**	**6.97**	**6.73**	**6.42**	**6.16**	**5.98**	
CD(0.05) T = 0.04; P = 0.09; T×P = 0.13 ; CV% =1.11														
T_1= Control extruded food; T_2= Ragi and milk solids based extruded food, Values are mean of three replications.														

Table.2 Influence of storage period on physico-chemical characteristics extruded snack foods

Types of extruded food	Storage period (days)													Average (treatments)
	0	10	20	30	40	50	60	70	80	90	100	110	120	
Moisture (%)														
T_1	3.67	3.81	4.12	4.29	4.37	4.46	4.52	4.65	4.81	4.89	5.03	5.10	5.15	4.53
T_2	3.41	3.51	3.63	3.76	3.81	3.95	4.10	4.22	4.31	4.45	4.63	4.76	5.02	4.12
Average of periods	3.54	3.66	3.88	4.03	4.09	4.20	4.31	4.43	4.56	4.67	4.83	4.93	5.08	
CD(0.05) T = 0.01; P = 0.03; T×P = 0.05; CV% =0.69														
Water Activity (a_w)														
T_1	0.334	0.341	0.352	0.357	0.364	0.371	0.380	0.392	0.421	0.436	0.482	0.484	0.496	0.397
T_2	0.329	0.332	0.341	0.349	0.353	0.360	0.370	0.380	0.402	0.422	0.436	0.449	0.493	0.387
Average of periods	0.331	0.336	0.346	0.353	0.358	0.366	0.375	0.386	0.411	0.429	0.459	0.466	0.494	
CD(0.05) T = 0.030; P = 0.002; T×P = 0.005; CV% =0.74														
Bulk density(g/cm^3)														
T_1	0.121	0.125	0.131	0.140	0.150	0.152	0.159	0.169	0.169	0.180	0.188	0.195	0.200	0.157
T_2	0.100	0.121	0.127	0.131	0.134	0.143	0.152	0.158	0.159	0.172	0.175	0.183	0.187	0.147
Average of periods	0.110	0.123	0.129	0.135	0.142	0.147	0.155	0.163	0.164	0.175	0.179	1.81	0.191	
CD(0.05) T = 0.02; P = 0.07; T×P = 0.9; CV% = 0.78														
Apparent Density (g/cm^3)														
T_1	0.507	0.519	0.523	0.527	0.536	0.542	0.548	0.600	0.615	0.635	0.642	0.710	0.790	0.591
T_2	0.700	0.712	0.730	0.740	0.756	0.769	0.790	0.810	0.840	0.866	0.901	0.915	0.966	0.807
Average of periods	0.603	0.615	0.626	0.633	0.638	0.655	0.669	0.705	0.725	0.750	0.812	0.812	0.878	
CD(0.05) T = 0.012; P = 0.031; T×P = 0.043; CV% =3.55														
Expansion Ratio														
T_1	4.06	4.00	3.90	3.80	3.76	3.75	3.67	3.60	3.59	3.55	3.50	3.49	3.48	3.70
T_2	4.12	4.10	4.04	3.97	3.93	3.82	3.79	3.75	3.65	3.60	3.54	3.52	3.50	3.79
Average of periods	4.09	4.05	3.97	3.88	3.84	3.78	3.73	3.67	3.62	3.57	3.52	3.50	3.49	
CD(0.05) T = 0.068; P = 0.173; T×P = 0.244 ; CV% =3.09														
T_1= Control extruded food; T_2= Ragi and milk solids based extruded food, Values are mean of three replications.														

Table.3 Influence of storage period on textural characteristics of extruded snack foods

Types of extruded food	Storage period (days)													Average of treatments
	0	10	20	30	40	50	60	70	80	90	100	110	120	
Hardness (N)														
T_1	4.87	5.20	5.52	5.64	5.80	6.00	6.29	6.81	7.14	7.33	7.54	9.31	11.23	6.82
T_2	4.15	4.24	4.40	4.55	4.79	5.16	5.38	5.80	6.20	6.90	8.29	9.10	10.51	6.11
Average of periods	4.51	4.72	4.97	5.10	5.30	5.58	5.83	6.31	6.67	7.11	8.80	8.32	10.87	
CD(0.05) T = 0.08; P = 0.21; T×P = 0.30 ; CV% =2.84														
Fracturability (mm)														
T_1	38.93	38.92	38.90	38.73	38.37	38.29	37.90	37.74	37.29	37.16	36.90	36.60	36.54	38.48
T_2	41.33	39.37	39.25	38.73	38.56	38.28	38.19	38.12	38.06	37.74	36.93	36.39	36.10	38.41
Average of periods	39.15	38.67	38.54	38.52	38.50	38.27	37.92	37.72	37.67	37.45	36.92	36.49	36.30	
CD(0.05) T = NS ; P = 0.42; T×P = 0.06; CV% =0.09														
T_1= Control extruded food, T_2= Ragi and milk solids based extruded food, Values are mean of three replications.														

Table.4 Influence of storage period on SPC count of extruded snack foods

Types of extruded food	Storage period (day)													Average of treatments
	Standard Plate Count (log cfu/g)													
	0	10	20	30	40	50	60	70	80	90	100	110	120	
T_1	4.10	4.12	4.13	4.17	4.19	4.21	4.23	4.28	4.31	4.38	4.54	4.63	4.65	4.30
T_2	4.00	4.05	4.09	4.11	4.16	4.19	4.23	4.31	4.33	4.37	4.41	4.45	4.51	4.23
Average of periods	4.05	4.08	4.22	4.11	4.17	4.20	4.23	4.29	4.32	4.37	4.47	4.54	4.58	
CD(0.05) T = 0.026; P = 0.066; TP = 0.93; % CV =1.49														
T_1= Control extruded food T_2= Ragi and milk solids based extruded food Values are mean of three replications.														

The change in hardness of the product may be observed due to the starch gelatinization and texture of the final product. Previous studies also reported that the hardness of the product increased due to increase in the moisture content of the product (Badrie and Mellowes, 1991).

The fracturability of control sample T_1 and ragi and milk solids extruded snack food T_2 decreased from 38.93 mm and 41.33 mm to 36.54 mm and 36.10 mm respectively at the end of 120 days of storage at room temperature (37±2ºC). The changes in the values of fracturability among the treatments was non significant (T_1 and T_2) and the interaction effect between the treatments and periods were significant (P<0.05) for fracturability. This shows that there is significant (P<0.05) effect of change in formulation on storage stability of product with respect to fracturability.

Marques *et al.,* (2017) demonstrated that the initial hardness of extruded snack coated with corn samples as 6.59 N, which was increased up to 16.04 N during 45 days of storage.

Changes in the Microbial Quality of Ragi and Milk Solids Based Extruded Snack Food during Storage

Standard Plate Count (SPC) is a collective enumeration of the overall microbiological quality of the product after production and during its storage period. Standard Plate Count (SPC) gives the idea about the status of RMESF in terms of its microbiological quality during storage. The Standard plate count ($\log_{10}$ cfu/g) of T_1 and T_2 increased from 4.10 and 4.00 on zero day to 4.65 and 4.51 respectively at the end of 120 days of storage at room temperature (37±2ºC) shown in table 4.

The changes in the SPC count among the treatments T_1 and T_2 and the interaction effect between the treatments (T_1 and T_2) and periods were significant (P<0.05). This was expected because none of the microorganisms, including bacteria as well as molds and yeasts, are able to grow in water activity less than 0.60 and water activity of both experimental samples were below 0.6 throughout the storage. Pawar *et al.,* (2012) observed that standard plate count of egg based snack food decreased gradually from the initial value of 4.4 to 3.3 log cfu/g when stored for 6 months at ambient temperature. Throughout the storage study yeast and mould count and coliform count not detected in both experimental samples T1 and T2.

The ragi and milk based extruded snack food and control sample were stored at room temperature (37±2 °C) significantly over a period of 120 days of storage. The moisture content decreased while water activity of experimental sample and control increased at the end of 120 days of storage at room temperature (37º±2 ºC). Textural characteristics viz. hardness increased while the changes in the fracturability among the treatments and the interaction effect between the treatments and periods were significant. The Standard plate count of both, experimental sample and control, increased at the end of 120 days of storage at room temperature (37º±2 ºC). Coliform and yeast and mold count were not detected in both experimental samples throughout the study period. The overall acceptability score of ragi and milk based extruded snack food was below 6.0 on 120th day of storage hence it was concluded that ragi and milk based extruded snack food packaged in MET PET was acceptable up to 110 days of storage at 37±2 ºC.

References

Ali, H., Mansour, E., Osheba1, A., and ElBedawey, A. (2016). Evaluation of extruded products prepared from corn grits – corn starch with common carp fish. *American Journal of Food Science and Nutrition Research,* 3 (5), 102-108.

Badrie, N., and Mellowes, W. A. (1991). Texture and microstructure of cassava flour extrudate. *Journal of Food Science,* 56 (5), 1319-1322, 1364. https://doi.org/10.1111/j.1365-

2621.1991.tb04762.x

Brennan, M. A., Derbyshire, E., Tiwari, B. K., and Brennan, C. S. (2013). Ready-to-eat snack products: the role of extrusion technology in developing consumer acceptable and nutritious snacks. *International Journal of Food Science and Technology*, 48 (5), 893-902. https://doi.org/10.1111/ijfs.12055

Bureau of Indian Standards Handbook, (BIS: Part XI, 1981). Handbook of Food analysis, Dairy Products. Indian Standards Institution, ManakBhavan, New Delhi.

Butt, M. S., Nasir, M., Akhtar, S., and Sharif, K. (2004). Effect of moisture and packaging on the shelf life of wheat flour. *International Journal of Food Safety*, 4 (1), 1-6.

Cai, W., Diosady, L. L., and Rubin L. J. (1995). Degradation of wheat starch in a twin-screw extruder. *Journal of Food Engineering*, 26 (3), 289-300. https://doi.org/10.1016/0260-8774(94)00056-F

Charunuch, C., Tangkanakul, P., Rungchang, S., and Sonted, V. (2008) Application of mulberry (*Morus alba* L.) for supplementing antioxidant activity in extruded Thai rice snack. *Kasetsart Journal of Natural Sciences*, 4 (2), 1-9.

Conti-Silva, A. C., Bastos, D. H. M., and Areas, J. A. G. (2012). The effects of extrusion conditions and the addition of volatile compounds and flavor enhancers to corn grits on the retention of the volatile compounds and texture of the extrudates. *International Journal of Food Science and Technology*, 47 (9), 1896-1902. https://doi.org/10.1111/j.1365-2621.2012.03047.x

Huber, G. (2001). Snack foods from cooking extruders. In Lusas, E. W. and Rooney, L. W. (Eds.), *Snack Food Processing* (pp.315-367). Baca Raton, Florida: CRC Press.

Launay, B., and Lisch, J. M. (1983). Twin-screw extrusion cooking of starches: Flow behaviour of starch pastes, expansion and mechanical properties of extrudates. *Journal of Food Engineering*, 2 (4), 259-280. https://doi.org/10.1016/0260-8774(83)90015-8

Marques, D. R., Berwig, K., Monteiro, C. C. F., Oliveira, D. M., and Monteiro, A. R. G. (2017). Shelf life evaluation of extruded snacks coated with maize starch to eliminate the use of fats in the flavoring process. *Chemical Engineering Transactions*, *57*, 1921-1926. https://doi.org/10.3303/CET1757321

Mehta, H. (2016). Development of extruded corn based snack food product incorporating minced chicken meat (Master of Technology thesis, University of Punjab agricultural University, Ludhiana, Punjab).

Nissar, J. Ahad, T. Naik, H. R., Hussain, S. and Rather, A., H. (2017). Studies on storage stability of corn based apple incorporated breakfast snacks. *International Journal of Chemical Studies*, 5 (6), 839-841.

Patel, S., and Verma, V. (2013). Value added products from nutri-cereals: Finger millet (*Eleusine coracana*). *Emirates Journal of Food and Agriculture*, 3 (4), 169-176. https://doi.org/10.9755/ejfa.v25i3.10764

Pawar, D., Raj, K., and Modi, V. K. (2012). Physico-chemical, microbiological and sensory characteristics of egg basede snack food. *Journal of Scientific and Industrial Research*, 71 (12), 777-787.

Raja, W., Kumar, S., Bhat, Z., and Kumar, P. (2014) Effect of ambient storage on the quality characteristics of aerobically packaged fish curls incorporated with different flours. *Springer Plus*, 3 (1), 106. https://doi.org/10.1186/2193-1801-3-106

Sebastian, R. S., Cleveland, L. E., and Goldman, J. D. (2008). Effect of snacking frequency on adolescents' dietary intakes and meeting national recommendations. *Journal of Adolescent Health*, 42 (5), 503-511. https://doi.org/10.1016/j.jadohealth.2007.10.002

Sharma, S., Mansour, M., Bobade, H., Kaur, G., and Singh, B. (2015). Product characteristics and storage stability of millet-cowpea extruded snacks. *Agricultural Research Journal*, 52 (4), 68-72. https://doi.org/10.5958/2395-146X.2015.00065.4

Singh, G., Singh, B., Sharma, S., and Singh, A. (2017). Development and storage study of maize and chickpea based extruded snacks. *International Journal of Current Microbiology and Applied Sciences*, 6 (10), 4798-4804. https://doi.org/10.20546/ijcmas.2017.610.447

Tahnoven, R., Hietanen, A., Sankelo, T., Kortaniemi, V. M., Laakso, P., and Kallio, H. (1998). Black currant seeds as a nutrient source in breakfast cereals produced by extrusion cooking. *Journal of Food Investigation Research*, 206 (5), 360-363.

Zheng, X., and Wang, S. S. (1994). Shear induced starch conversion during extrusion. *Journal of Food Science*, 59 (5), 1137-1143. https://doi.org/10.1111/j.1365-2621.1994.tb08210.x

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