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Effect of extrusion processing parameters on hardness and crispiness of milk protein-maize based extrudates

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Abstract
Textural properties of extrudates which are perceived by the final consumers are the main quality criteria. We studied the important textural characteristics of extrudates, hardness and crispiness of extrudates from different blends of milk protein and maize flour as affected by screw speed of extruder during extrusion processing. These texture qualities have great influence on the acceptability of innovative products. Maize flour was extruded with milk proteins at different levels of protein content 4%, 6%, 8%, different feed moisture content 12%, 14%, 16%, different feed rpm 340 rpm, 380 rpm with constant extrusion temperature 100°C. Addition of milk protein resulted in higher hardness, lower crispiness product due to network formation between protein and starch matrix, increasing the feed moisture resulted in higher hardness and increasing the screw speed resulted in lowering hardness with higher crispiness in the milk protein – maize based extrudates.

Keywords: texture, extrusion, whey protein concentrate, rennet casein, hardness, crispiness

Introduction
Extrusion processing is an emerging high-temperature short-time (HTST) food processing technology, gaining importance in certain industries due to its versatility. It can be considered as a "Green food processing technology" since the energy and water consumption was less and it safeguards the environment with less effluents. Extrudates are of major importance in the food and pet food industries today. Twin screw - extruders can be used for production of numerous new products (cereal baby food, confectionery, breakfast cereals, snack foods, bakery products, pastas, pet food and meat products) (Wiedemann & Strobel 1987) [6].

During extrusion process, the treatment of the raw material consists of mixing, kneading, heating, shearing, and finally extruded through a die and dry the product under expansion and rapid fall in pressure (Akdogan 1999) [1].

Gelation, molecular disintegration of macromolecules, denaturation of proteins and other network formation between the molecules (Chinnaswamy, 1993) [3]. A high temperature, short time (HTST) procedure uses raw material in short residence time, high temperature, high pressure, large shear forces and intensive mixing for the production of various types of extrudate in different shapes (Zheng & Wang 1994) [7].

The quality of extrudate produced can be determined using different methods according to their applicability in a variety of food-industry sectors. Sensory qualities include aspects of the food product that can be adequately evaluated by the consumer. These include colour, size, shape, taste, odour and structure.

A sensory panel member subjectively evaluates the structure of a product, usually in the form of acceptability and preference. In the ideal case, an objectively determined physical parameter of structure, such as hardness and crispiness is evaluated in relation to the final consumer's acceptability or preference, and proves very useful in predicting the final reaction.

The objective of our study is to determine the effect of process parameters (feed moisture content, protein source, and their level of addition and screw speed) on the textural properties of milk protein – maize based extrudates.

Materials and Methods

Sample preparation

Maize grains and Milk protein sources were procured from Karnal Farmer and Modern Dairies Ltd., Karnal, Haryana, India respectively. The proximate composition of the raw materials is shown in Table 1. Level of milk proteins in formulation was adjusted by using requisite quantity of rennet casein/WPC-70. Maize flour and milk proteins viz., WPC-70/ Rennet casein were dry-blended by passing through sieve (2 mm) and calculated water was sprayed over it to adjust 12, 14 and 16 % moisture in pre-mix. The mixture was again passed through 2 mm size sieve and blended for 15 min to obtain a uniform mixture. The pre-mix was packaged in 1 kg LDPE bag and stored overnight for equilibration of moisture.

Table 1: Proximate composition of raw materials

Raw material	Moisture (%)	Crude protein (%)	Fat (%)	Total ash (%)	CHO* (%)
Maize flour	5.8±0.04	8.1±0.06	2.93±0.03	1.56±0.01	81.61
Rennet Casein	8.85±0.04	80.14±0.44	0.94±0.04	7.92±0.02	2.15
WPC-70	3.86±0.27	69.68±0.46	4.76±0.05	3.85±0.19	17.85

Values are mean± S.E (n=3); * difference

Extrusion cooking

A twin screw extruder (Basic Technology Pvt. Ltd., Kolkata, West Bengal, India) was used for the preparation of extrudates. It consists of a feeder and extrusion cylinder having two heating zones. A circular die (4mm diameter) at the exit of the barrel was used for extrusion. The extruder was provided with the water circulation jacket at the exit of the extrusion cylinder for temperature control. The conditioned mixture was fed to feed hopper equipped with screw augers to load materials into the barrel at uniform rate. The extruder screw speed was set in varied level i.e 340 rpm and 380 rpm. The temperature of inlet and outlet cooking section was set to 40°C and 100°C, respectively. The plasticized mass was passed through 4 mm die and extruded samples were dried in a tray drier for 30 min at 50°C or till the final moisture reached in the range of 3-5% moisture. The dried samples were collected and stored in the appropriate laminated bags for further analysis.

Texture analysis

Hardness and crispiness were determined using TA-XT2i (Stable Micro systems, UK). Texture analyzer fitted with a 25 kg load-cell. Test conditions used for testing hardness and crispiness were pre – test speed 2.0 mm/sec, test speed 1.0 mm/sec, post – test speed 2.0 mm/sec. The probe used was HDP/BSW (Warner-Bratzler Blade) to determine hardness which is the peak force during compression of the product and crispiness which is the total number of positive peaks.

Statistical analysis

The data obtained for all the experiments were analysed using Microsoft excel 2010 to get mean and standard error.

Results and Discussion

Hardness

The hardness of extruded product is associated with the expansion and cell structure of the product. It is the average force required for a probe to penetrate the extrudate. The range of hardness of extrudates was 23.33 - 43.33 N at 340 rpm and 9.11-30.68 N at 380 rpm screw speed. Increasing the screw speed resulted in less hardness products. Similar trend was found by Brncic *et al.,* (2006) in wheat starch based extrudates. Addition of rennet casein to the maize flour at varied level of protein with varied feed moisture showed higher hardness when compared with the WPC- 70 incorporated samples in all variation.

Increasing the feed moisture also increased the hardness value of the prepared product. Similar trend was recently reported by Seth *et al.,* (2015) [5] who observed a significant increase in harness with increase in feed moisture content increased hardness significantly, which attributed to reduction in expansion of the extruded product and lower rate of starch degradation at higher moisture values. Protein rich extrudates produce less expandable products and more rigid network resulting in higher resistance to shear and lower expansion (Li *et al.,* 2005) [4].

Table 2: Hardness and crispiness of milk protein-maize based extrudates as affected by extrusion screw speed

Textural properties	Hardness (N)		Crispiness *	
Treatment codes	340 rpm	380 rpm	340 rpm	380 rpm
C414	28.39±5.25	22.65±2.5	14±1.77	22.71±2.44
C612	35.84±2.52	29.37±1.26	23.28±1.87	32.57±3.16
C616	38.96±9.6	30.68±2.55	24.42±1.26	26±3.84
C814	43.33±4.97	16.56±3.27	23.85±2.14	27±2.56
W414	23.23±2.5	9.11±1.15	20±2.62	26.28±2.50
W612	23.37±4.05	14.86±0.7	22±2.09	38.14±3.81
W616	25.38±3.4	13.70±1.9	22.57±3.8	25.28±1.91
W814	57.03±6.6	15.05±3.8	22.57±4.05	30.86±1.9

Treatment codes: C414- 4% rennet casein + 14% moisture+ maize flour; C612- 6% rennet casein + 12% moisture+ maize flour; C616 - 6% rennet casein + 16% moisture+ maize flour; C814 - 8% rennet casein + 14% moisture+ maize flour; W414 - 4% WPC-70 + 14% moisture+ maize flour; W612 - 6% WPC-70 + 12% moisture+ maize flour; W616 - 6% WPC-70 + 16% moisture+ maize flour; W814 - 8% WPC-70+ 14% moisture+ maize flour;

Values are Mean ± S.E (from 7 determinations).

***** No of positive peaks in force deformation curve of texture analysis.

Crispiness

Crispness test was performed to give an idea of the resistance, which the extrudate may offer, on first bite to the consumer. In this test number of peaks were observed that the maximum number of peaks give the better crisp product. The crispness of extrudates ranged between 14 – 24.42 at 340 rpm and 22.71 – 38.14 at 380 rpm. Since increasing the screw speed resulted in less hardness, definitely the crispiness will be higher (Brncic *et al.,* 2006). Similar trend of result have been seen in our study also with higher crispiness product which is more suitable for protein enriched snack base.

Conclusion

Incorporation of milk proteins into maize composite extrudates improved the nutritional value, where it increased protein content of the wholesome product. The product developed will create new domestic and export market opportunities for the dairy as well food industry since the product is acceptable with good textural properties.

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