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Development and Evaluation of Corn Starch Fortified Read-To Eat Extruded Product

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Abstract
The present study entitled "Development and evaluation of corn starch fortified Read-to Eat Extruded product)" was carried out in the laboratories of Department of Food Technology, RIMT University. Mandi Gobindgarh, Punjab. The study was conducted with the objectives to develop and evaluate corn starch fortified Read-to Eat Extruded product
Various proportions of corn starch with rice and maize grit were blended. The control and corn starch fortified extruded snacks were packed and preserved for 60 days at ambient temperature (30+2°C) for determining its quality and sensory characters at 30 days intervals. During storage the moisture content increased, decrease in crude fat, crude protein, ash and crude fiber, in corn starch fortified Read-to Eat Extruded product during storage. The corn starch fortified Read-to Eat Extruded product scored greater as compared to control in organoleptic evaluation. Acceptable ready to eat corn starch fortified product can be developed by incorporating 15 percent corn starch in formulation of rice and maize grit.

Keywords: Extruded, storage, Physco, chemical, maize, cultivars.

1. Introduction:

Maize (*Zea mays* L.), commonly known as corn, holds a significant position as a crucial global crop, thriving across diverse climatic conditions due to its exceptional adaptability. It stands out as the leading grain crop worldwide and plays a vital role in human nutrition. Being the most extensively cultivated food crop globally, maize surpasses even rice and wheat in terms of popularity (FAOSTAT 2018). In numerous developed countries, maize, also known as corn (Zea mays L.), holds the status of a staple food and serves as crucial animal feed and a bio-energy source for ethanol production. Belonging to the Poaceae family, maize is a significant annual cereal crop with deep historical roots. Its name "Zea" originates from ancient Greek, signifying "sustaining life," while "Mays" comes from the Taino language, translating to "life giver." The Spanish term "maiz" evolved into the widely recognized word "maize" for this plant. Additionally, there are several synonyms such as zea, silk maize, makka, barajovar, among others, that are used to refer to the plant (Kumar & Jhariya, 2013). Maize holds the status of a staple food in many regions across the globe and ranks as the third most significant crop after rice and wheat (Sandhu & Singh, 2007).
Maize is a major crop of ancient culture and is still crucial part of the staple food of many countries around the world. Corn has gone through a process of selection and improvement that produces many kernel types. Due to its great genetic diversity, today's maize does not have the similar chemical composition, with differences in its properties and end-use. For example, corn produces a variety of products such as breakfast cereals and snack foods (Salinas-Moreno, Martínez-Bustos, Soto-Hernández, Ortega-Paczka, & Arellano-Vázquez, 2003). and the starch is separated (Ji et al., 2003). The corn starch yield and purity are highly influenced by the variation among corn cultivars and wet milling conditions used for isolation of starch. Corn starch is widely used as a gelling agent, thickener, bulking agent and water retention agent in food industry (Eliasson, 2004; N. Singh, Singh, Kaur, Sodhi, & Gill, 2003). Starch is present in plants as semi crystalline granules and comprised of linear amylose and branched amylopectin chains (Gallant, Bouchet, & Baldwin, 1997) and corn is categorized as normal, waxy and high amylose corn on the basis of amylose to amylopectin ratio (Sandhu & Singh, 2007). Waxy corn starch is mainly composed of amylopectin (~99 %) and a very less amount of amylose (~1 %) is present. The structure, composition, distribution and granular packing of amylose and amylopectin depend upon the origin of starches (Kurakake,

Akiyama, Hagiwara, & Komaki, 2009). Amylose content and amylopectin branch chain length plays a central role in determining the pasting properties of corn starches (Tziotis, Seetharaman, Klucinec, Keeling, & White, 2005). Starch gelatinization determines the thickening and swelling characteristics of starches for their potential use in food industry as thickener (Karim et al., 2007). The porosity of corn starch granules is studied using microscopic techniques (Fannon, Hauber, & BeMILLER, 1992; Sujka & Jamroz, 2013) and this porous structure facilitates the diffusion of enzymes (Dhital et al. 2010), proteins, peptides and volatile compounds (Zeller, Saleeb, & Ludescher, 1998) with impact on texture and mechanical properties (Rahman, 2001). The high crystallinity of waxy corn starch granules is related to the amylopectin branch chain length that is different for normal corn starches .The distinct behavior of waxy starches increases their demand as stabilizer in food industry and as adhesive in paper industry (Ptaszek et al., 2009).

Starches are used widely in the food industry because of their physicochemical properties (such as retrogradation and gelatinization) and functional properties (such as solubility, water absorption, swelling, syneresis) and rheological properties. In starch granules, amylose and amylopectin are compounds that are determined by the molecular and structural compositions, and the percentage composition and arrangement of these two homo polysaccharides. These factors determine the granule size and shape influenced by the species of plant (Santana & Meireles, 2014). Various properties of starches such as physico-chemical, rheological, thermal and retrogradation properties have been essentially connected with the amylose/amylopectin ratio, granule size, and mineral content (J. Singh & Singh, 2003).

The study was undertaken to investigate and compare with different varieties of cultivars by physicochemical, thermal, morphological and pasting properties. As the major source of energy is starchy foods in our diet, healthier starchy foods giving beneficial functionalities are essential to sustain good health. Therefore, it is of interest to study the starch content from maize which incorporates into various products. Hence, the present study entitled “production and utilisation of starch from selected maize cultivars” was undertaken with the following objectives.

2. Materials and Methods

The cultivar (JC-12 ,HP-white, Kanchan and P-1844) of maize were procured from Eternal University, Baru Sahib, Local farmers of Punjab and Himachal Pradesh. The starch isolated from these cultivars was used for development of corn starch fortified ready-to-eat extruded product. The chemicals used were obtained from Sigma-Aldrich Chemicals Pvt. Ltd. New Delhi (India).

2.1. Preparation of ready-to-eat extruded snacks

For the preparation of ready-to-eat extruded snacks, various level of Maize starch (0, 10, 20 and 37%) were incorporated into maize and rice flour. The process for preparation of ready-to-eat extrudates was standardized with Response Methodology (RSM) experimental design (Table3.2). Seventeen samples in total were prepared , where feed composition (73-100%) was subjected to various Surface levels of feed moisture (13-22%)and cutter speed(7-10 rpm) at 121 ^{0}C extruder temperature and 25 kg/hr feed rate. Ingredient formulations containing maize flour, rice grit and maize starch were mixed as per design and different moisture levels were adjusted into the flour blends by tempering with calculated quantity of water. For uniform distribution, mixture was sieved two-three times. The mixture was kept for 30 minutes at room temperature and remixed before extrusion. The extrudates were prepared using BTPL lab model twin-screw extruder fitted with rotating cutter and extrudates were collected in a trough.

2.2. Experimental design and data analysis by RSM

The central composite rotatable design (CCRD)for the three independent variables was performed. The independent variables considered were feed composition(A),moisture content(B) and cutter speed (C).The independent variables and variation levels are shown inTable1. Various

Table: 1: Levels of independent variables for the experimental design

Symbol	Independent variables	Low level	Mid-level	High level
A	Feed Composition (%)	73.0	90.0	100.0
B	Moisture (%)	13.0	18.0	22.0
C	Cutter Speed (rpm)	7.0	9.0.0	10.0

Response surface methodology was applied for experimental data, a statistical package of design-expert version 8.0.6 software (Stat-Ease Inc., Minneapolis, MN,USA)for generation of response surface plots and for statistical analysis of experimental data. The results were analyzed by a quadratic regression method, which describes the effects of variables in the models derived.

2.3. Quality evaluation of corn starch extruded products

The moisture content was determined by following the method given by (Horwitz, 1975). Crude Ash content of the samples is described by using procedure described by AACC (2000). Crude protein was analyzed following micro-kjeldhal method as per the procedure described in AACC (2000) with Kjeldhal Unit (Pelican). Crude fat was determined as per method described by (Rangnna, 2007) using Soxoplus (Pelican). Crude fiber was estimated by standard method of analysis AACC (2000) using Automatic Fibraplus unit. The corn starch fortified RTE extruded snacks were evaluated. The organoleptic evaluation was done by a panel of 10 semi trained panelist by using hedonic rating scale as explained by (Rangnna, 2007). The samples were analyzed for colour and appearance, flavour, taste, texture and overall acceptability. The overall acceptability of the corn starch fortified RTE extruded snacks were based on the mean scores obtained from all the sensory characters. The data received in the present study were subjected to analysis of variance (ANOVA) techniques and Response Surface Methodology (RSM) in central composite rotatable design.

3. Results and discussion

The Moisture of corn starch fortified RTE extruded snacks and the change in moisture content during storage is explained in Table 2 There was little but significant increase in moisture content of corn starch fortified RTE extruded snacks. The average moisture content increased from 3.47 to 5.24 percent during 60 days of storage. The maximum moisture content 5.0 percent was observed in T_3 which contains 15 percent starch and minimum was observed in control. The moisture increase in the product during the storage can be compared with the Continuous with the hygroscopic nature and porous structure of the product (Nazir, Salim, Naik, & Hussain, 2017) and nature of packaging material (Nagi, Kaur, Dar, & Sharma, 2012).

Table 2.: Effect of different treatments and storage period on moisture content (%) of corn starch fortified RTE extruded snacks

Treatment	Storage Period in days			
	0	30	60	Mean
T_0	2.5 ±0.25	3.6±0.3	4.1±0.2	**3.4**
T_1	3.5 ±0.20	4.0±0.2	4.4±0.2	**4.0**
T_2	4.0 ±0.20	4.5±0.2	5.6±0.3	**4.7**
T_3	4.2 ± 0.20	5.0±0.3	5.9±0.4	**5.0**
T_4	4.5 ±0.20	5.2±0.1	6.2±0.2	**5.3**
Mean	**3.74**	**4.46**	**5.24**	
CD at 5 %	**Treatment = 0.24.; Storage = NS; Treatment × Storage = 0.43**			

The ash content of various combinations of maize corn starch fortified RTE extruded snacks and changes during storage are given in Table 3. There was slight decrease in the ash content of corn starch fortified RTE extruded snacks from 2.20 to 2.09 percent during the storage periods. The maximum increase was found in T_4 with 20 percent starch and the minimum was observed in control. The interaction between treatments and storage was found to be non-significant. The interaction with other components like proteins and carbohydrates is the reason for decrease in ash content during storage (Akhtar, Anjum, & Ahmed, 2005). Similar decrease in ash content was observed by (Nasir, Akhtar, & Sharif, 2004)

Table 3. Effect of different treatments and storage period on Ash content (%) of corn starch fortified RTE extruded snacks

Treatment	Storage Period in days			
	0	30	60	Mean
T_0	1.19 ± 0.15	1.17 ±0.10	1.15 ±0.08	**1.2**
T_1	2.44 ± 0.15	2.38 ±0.10	2.33 ±0.08	**2.4**
T_2	2.50 ± 0.21	2.48 ±0.15	2.45 ±0.13	**2.5**
T_3	2.69 ± 0.32	2.66 ±0.26	2.65 ±0.24	**2.7**
T_4	2. 97 ± 0.22	2.95 ±0.16	2.90 ±0.13	**2.9**
Mean	**2.20**	**2.13**	**2.09**	
CD at 5 %	**Treatment = 0.24.; Storage = NS ; Treatment × Storage = 0.43**			

The protein content of maize starch incorporated ready to eat extruded snacks was presented in Table 4. The average crude protein content was 9.82 percent at 0 day and 9.11 percent at 60day. The decrease in protein content during the storage was attributed to denaturation of protein to amino acids (Parimita & Arora, 2015) and hydrolysis of protein bonds due to enzymatic action (Premlatha, Jothilakskmi, & Kamalasundari, 2010). Similar findings were also observed by (Slathia, 2014) in mong bean based noodles.

Table 4: Effect of different treatments and storage period on crude protein (%) of corn starch fortified RTE extruded snacks

Treatments	**Storage Period in days**			
	0	**30**	**60**	**Mean**
T_0	10.50 ±0.05	10.00 ±0.1	9.80 ±0.15	**10.1**
T_1	10.28 ±0.4	9.90 ±0.5	9.75 ±0.45	**10.0**
T_2	9.76 ±0.2	9.50 ±0.1	9.25 ±0.25	**9.5**
T_3	9.56 ±0.25	9.10 ±0.3	8.75 ±0.25	**9.1**
T_4	9.02 ±0.20	8.20 ±0.3	8.00 ±0.35	**8.4**
Mean	**9.824**	**9.340**	**9.11**	
CD at 5 %	**Treatment = 0.24.; Storage = NS ; Treatment × Storage = 0.43**			

There was positive decrease in the protein content of corn starch fortified RTE extruded snacks during the 60 day of storage. The maximum protein content was observed in T_1 (control) and minimum was observed in T_4 (20 % MS). The significant interaction between the treatment and storage was established. The fat content of various combinations of maize starch incorporated ready to eat extruded snacks and change in it during the storage was presented in Table 5. There was slight decrease in fat content of corn starch fortified RTE extruded snacks with increasing storage period. The average fat content of corn starch fortified RTE extruded snacks at 0 day was 1.98 percent and decreased to 1.77 percent at the end of storage period. Among the treatments the maximum fat content was observed in T_1 (control). The non-significant interaction between the treatment and storage was established. The decrease in fat content might be due to enzyme lipase in mung bean based noodles(Slathia, 2014).

Table 5: Effect of different treatments and storage period on crude fat (%) of corn starch fortified RTE extruded snacks

Treatment	**Storage Period in days**			
	0	**30**	**60**	**Mean**
T_0	2.46 ± 0.34	2.30 ±0.1	2.35 ±0.3	**2.4**
T_1	1.86 ±0.1	1.75 ±0.3	1.65 ±0.3	**1.8**
T_2	1.86 ±0.1	1.72 ±0.43	1.62 ±0.1	**1.7**
T_3	1.86 ±0.1	1.70 ±0.41	1.60 ±0.3	**1.7**
T_4	1.86 ±0.1	1.75 ±0.41	1.63 ±0.1	**1.7**
Mean	**1.98**	**1.84**	**1.77**	
CD at 5 %	**Treatment = 0.24.; Storage = NS; Treatment × Storage = 0.43**			

The crude fibre of various treatments of corn starch fortified RTE extruded snacks and changes in it during storage are presented in Table 6. The significant decrease in the crude fibre of maize starch incorporated ready to eat extruded snacks with increasing storage period. The average crude fibre was 3.02 percent at zero days which reduced to 2.91 percent after 60 days of storage. Among the treatments the maximum crude fibre was found in T3 (15 percent starch). The non-significant interaction between the treatments and storage was established.

Table 6: Effect of different treatments and storage period on crude fiber (%) of corn starch fortified RTE extruded snacks

Treatments	**Storage Period (days)**			
	0	**30**	**60**	**Mean**
T_0	2.05±0.22	2.0 ±0.10	1.95 ±0.10	**2.0**
T_1	2.92 ±0.13	2.89 ±0.38	2.85 ±0.38	**2.9**
T_2	3.21 ±0.26	3.17±0.22	3.14 ±0.35	**3.2**
T_3	3.35 ±0.26	3.33 ±0.13	3.20 ±0.28	**3.3**
T_4	3.59 ±0.13	3.45 ±0.13	3.41 ±0.21	**2.0**
Mean	**3.024**	**2.968**	**2.910**	
CD at 5 %	**Treatment = 0.24.; Storage = NS ; Treatment × Storage = 0.43**			

The organoleptic evaluation of maize starch incorporated ready to eat extruded snacks was conducted for the attributes colour and appearance, taste, texture, flavor and overall acceptability. The 9-point hedonic scale was used for evaluation.The overall acceptability scores of various combination treatments of corn starch fortified RTE extruded snacks during storage are presented in Table 7. The decrease in overall acceptability scores of corn starch fortified RTE extruded snacks with increasing storage period was non-significant. The average overall acceptability score of maize starch incorporated ready to eat extruded snacks at 0-day was 8.1, which decreased to 7.6 by 60 days of storage. The non-significant interaction between treatment and storage was established. These results were in conformation with (Slathia, 2014) in mung bean based noodles during 3 months storage periods.

Table 7: Effect of different treatments and storage period on overall acceptability of corn starch fortified RTE extruded snacks

Treatments	Storage Period (Days)		
	0	60	Mean
T_0	8.0±0.04	7.6±0.50	**7.8**
T_1	8.3±0.08	7.5±0.10	**7.9**
T_2	7.9±0.1	7.5±0.10	**7.7**
T_3	8.2±0.01	7.9±0.5	**8.1**
T_4	8.0±0.04	7.6±0.12	**7.8**
Mean	**8.1**	**7.6**	
CD at 5 %	**Treatment = 0.24. Storage = NS; Treatment × Storage = 0.43**		

Conclusion:

From the present study it can be concluded that acceptable quality of corn starch incorporated RTE extruded snacks and can be prepared with 15% corn starch. The developed corn starch incorporated RTE extruded snacks remained acceptable upto 3 month of storage at room temperature.

Declarations

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

Ethical approval

This article does not contain any studies with animals or humans performed by any of the authors.

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