An experimental study of various whey proteins concentrates addition effects on some textural and physical properties of direct expanded maize extrudates

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Extrusion cooking represents a very effective process applicable in biotechnology and food industry. In food and fed industry, the products of extrusion cooking are of major importance today.

The issue of this work was to incorporate different amount of whey protein concentrate (WPC) in corn flour as raw material during extrusion cooking. For such a purpose a co-rotating twin screw extruder was used to obtain direct expanded extrudates.

Experimental data were analyzed with multiparameter correlation analysis by using software package Statistica 6. In this work a full factorial design of experiments with two independent variables in three levels (3^2) was used. Achieved textural properties of direct expanded extrudates with addition and without addition of whey protein concentrate as: extrudate diameter (d_e), expansion ratio (Er), extrudate straight length (ESL) and breaking strength index (BSI) in bending mode, and penetration mode as well were compared with versatile process parameters (feed moisture content and whey protein concentrate intake). Also water absorption index (WAI), and water solubility index (WSI) were also correlated with empirical models.

Keywords: extrusion, texture, whey protein concentrate

1. Introduction

Various innovated processes in food industry have replaced older and less efficient procedures. Such a processes are advantageous, more effective, cleaner and less expensive. Just a first step during purchasing of equipment is quite expensive. Everything else during food manufacturing with new type of devices offers versatile benefits.

During last twenty years use of extrusion in food producing is one of these technologies (LI et al., 2005). All kind of foodstuffs is possible to be produced with single-screw and twin-screw extruders. Breakfast cereals are growing market almost everywhere (Brnčić et al., 2006; Chinnaswamy, R. 2003). Food extrusion is defined as a cooking-extrusion process based on expanded, high voluminous, crispy and taste acceptable products-extrudates. These products are manufactured under conditions of high temperature of process and short residence time retention of raw material in each section of extruder (cooker). The extruder itself is divided in sections (Elsey et al., 1997). Each section has got it own purpose during extrusion-cooking.

With corn maize as based material a various concentrations of different proteins may be used such as soya and whey proteins. In this work to provide a product with higher protein amount some mixtures of corn maize and whey protein concentrate (WPC) were prepared. WPC was used to enrich direct expanded extrudates. Enrichment means that taste, color, crispiness, other textural-mechanical properties and complete amount of preserved proteins during processing should be balanced in best ratio (Onwulata et al., 2001).

Usefulness ratio of WPC is very strong in various food products (Herceg et al., 2004). The main problem is to establish conditions of extrusion for this temperature sensitive concentrated product. Therefore HTST (high temperature-short time) production must be adjusted. WPC must be well mixed with corn maize. This is necessary precaution because all above mentioned reasons.

Twin-screw extruder APV Baker, MPF 50:15 (co-rotating setup) was used for direct expanded extrudates manufacturing in this paper. The goal of this work was combine corn maize and WPC to achieve acceptable enriched direct expanded extrudate.

2. Materials and methods

Corn maize was purchased from the local market. WPC was purchased from producer MILEI, GmbH, Leutkircl and it has a commercial name Milacteal 60. It contains 60% of whey protein. Three mixtures of corn maize and WPC were made in following ratios: 5% of WPC and 95% of corn maize, 10% of WPC and 90% of corn maize and 15% of WPC and 85% of corn maize. Very important part of investigation was to determine Feed moisture content (FMC). After preliminary investigations FMC was established and it was hold during experimental part of work in: 10,08 L/h, 12,18 L/h, 14,28 L/h.

Before extrusion of mixtures three control samples of pure corn maize were extruded with above-mentioned FMC. Extrudate samples were marked as 1-3 CM (corn maize) and 1-9 CMW (mixtures of corn maize and WPC. Description of manufactured extrudates with markings is presented in table 1.

Table 1. Description of extrudates

SAMPLE	SAMPLE DESCRIPTION
1 CM	10,8 L/h FMC
2 CM	12,18 L/h FMC
3 CM	14,28 L/h FMC
1 CMW	10,8 L/h FMC, 5% WPC
2 CMW	12,18 L/h FMC, 5% WPC
3 CMW	14,28 L/h FMC, 5% WPC
4 CMW	10,8 L/h FMC, 10% WPC
5 CMW	12,18 L/h FMC, 10% WPC
6 CMW	14,28 L/h FMC, 10% WPC
7 CMW	10,8 L/h FMC, 15% WPC
8 CMW	12,18 L/h FMC, 15% WPC
9 CMW	14, 28 L/h FMC, 15% WPC

Processing conditions of twin-screw extrusion using APV Baker, MPF 50:15 co-rotating twin-screw extruder, used for extrudates manufacturing are presented in table 2.

Table 2. Procesing conditions

TWIN - SCREW EXTRUDER					
EXTRUSION PARAMETERS	EXTRUSION SETUP				
FMC (L/h)	10,8		12,18		14,28
rpm	300				
Temperature profile (°C)	30	60	90	110	130
Diameter of the die (mm)	4 × 2				
Mixture feed (kg/h)	70				

Textural properties of direct expanded extrudates were determined using TA-HD plus texture analyser produced by “Stable mycro systems”, Godalming, Great Britain. A bending mode was used and penetration mode as well.

Following textural properties of the extrudates were determined (some of them recalculated) within these investigations:

- extrudate diameter (d_e) – The sample was cut and diameter of cross section was measured using digital calliper. At least five measurements were performed for each sample. Arithmetic mean of samples was taken into consideration.
- expansion ratio (Er) – Represents value of the d_e divided with the extruder die.
- ESL was determined using digital calliper. A measuring of a minimum 10 extrudates (for each sample) was conducted. Result is length of extrudate from one to another side by measuring straight line.
- Hardness of the extrudates is the peak in the Force/Distance curve when the sample breaks (peak breaking force or collapse). BSI was calculated by dividing peak breaking force and d_e.

Water absorption index (WAI) and water solubility index (WSI) were also calculated using standard methods.

3. Results and discussion

Influence of difference concentrations of WPC addition and three different FMC on d_e are presented in figure 1. It can be observed that d_e is largest in the samples without WPC addition. For the first three control samples (WPC 0%), d_e is largest and for all other samples (with various concentrations of WPC) d_e has tendencies of decrease. Also, there is decrease of the d_e within the groups of the samples (WPC 0%, WPC 5%, WPC 10%, WPC 15%).

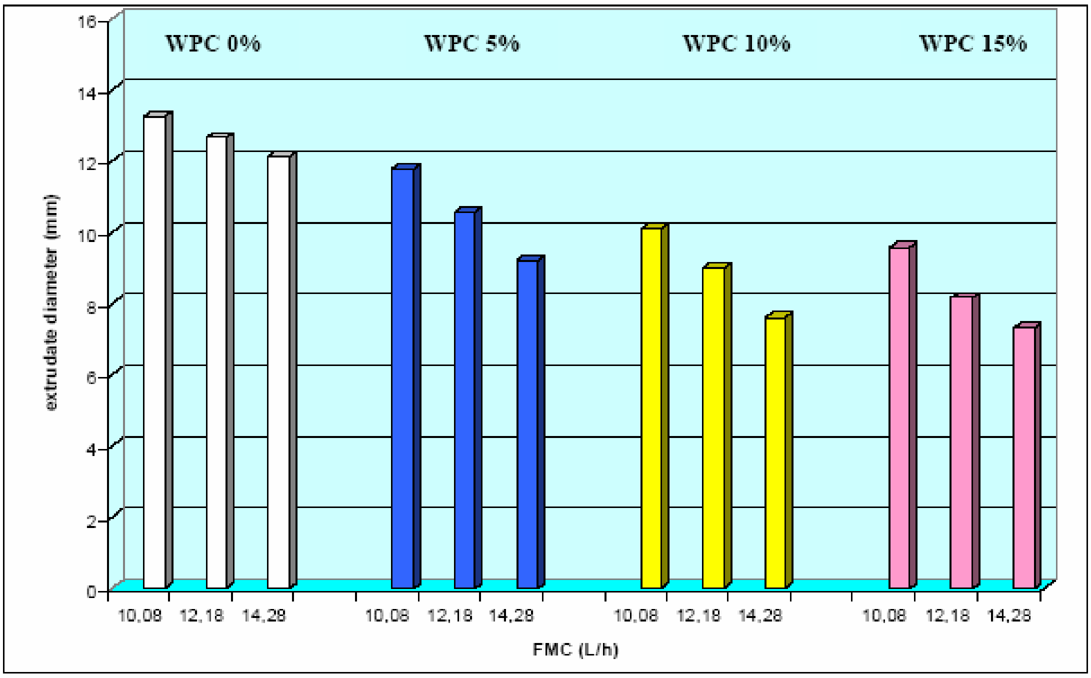

Figure1. Diameter of extrudates with and without WPC addition in dependence of FMC

Textural properties of all samples are presented in table 3. It can be observed that control samples (CM) are in higher values for d_e, ER and ESL than the samples with added WPC.

Sample 1 CMW had (among samples with WPC addition) higher values of d_e, ESL and ER, but that was in the same time sample with lowest amount of added WPC. Example of the sample 4 CMW is acceptable, with good d_e, ER and ESL, lowest amount of FMC but quite enough WPC (10%). Sample 9 CMW has got a lot of proteins (15%) and FMC (14,28 L/h) and its textural properties (compared with most of the samples presented in table 3) are not in acceptable range.

On the other hand WPC in direct expanded extrudates causes hardening of the samples that are very severe. Hardening of the sample is recalculated for the better understanding of WPC influence to corn maize properties (textural means), and BSI was presented in bending and penetration mode. Higher force was needed in bending than in penetration mode for each sample.

Table 3. Textural properties of all direct expanded extrudates

SAMPLE	d_e (mm)	SEI ili ER. d_e/d_d (mm/mm)	ESL. (mm)	BSI F/d_e	BSI PENETRATION F/d_e
1 CM	13,22	6,61	16	0,294	0,092
2 CM	12,65	6,34	15	0,326	0,184
3 CM	12,09	6,05	13	0,399	0,228
1 CMW	11,77	5,86	14	0,387	0,098
2 CMW	10,59	5,29	12	1,043	0,482
3 CMW	9,22	4,61	11	2,461	2,094
4 CMW	10,09	5,05	12	2,163	0,665
5 CMW	8,97	4,49	10	2,399	0,805
6 CMW	7,59	3,79	6,5	2,788	0,997
7 CMW	9,56	4,78	11	2,266	0,704
8 CMW	8,14	4,07	9	3,011	1,088
9 CMW	7,33	3,67	6	3,804	1,226

Interactions that explain relationships between extruded starches (CM in this experimental work) and water intake (FMC) are WAI and WSI. Changes in WAI and WSI are consequence of extrusion processing which occur rapidly in the beginning at the cooking zone of the device. It happens after the mixture is thrown in the extruder, than mixing and kneading. In other extruder zones changes in WAI and WSI are uniform.

Statistical analysis of process parameters influence on WAI and WSI is presented in tables 4 and 5 and equations 1 and 2 as well. In this study, the effect is considered significant if the p-value for each factor or interaction is less than 0,05.

Table 4. Influence of process parameters on WAI

	Coefficient	***p***
Intercept	12,23667	0,00000
WPC	0,85333	0,01895
Q_{H2O}	1,86667	0,00043
s^2 = 0,4307 R^2 = 0,9072 R^2_{adj} = 0,8763		

$$WAI = -0,2967 + 0,1138 * WPC - 0,8889 * Q_{H2O} \qquad /1/$$

Table 5. Influence of process parameters on WSI

	Coefficient	***p***
Intercept	14,93333	0,00000
WPC	-5,08333	0,00025
Q_{H2O}	-1,81667	0,03293
s^2 = 2,6028 R^2 = 0,9180 R^2_{adj} = 0,8907		

$$WSI = 35,637 - 0,6778 * WPC - 0,8651 * Q_{H2O} \qquad /2/$$

4. Conclusions

- Textural properties of the direct expanded extrudates are significantly influenced by interactions of CM and WPC.
- Severe increase of the BSI was established within the extrudates with higher amount of WPC and FMC as well.
- Higher force was needed to break the extrudates in bending than in penetration mode for each sample.
- Extrudates with WPC addition were harder than pure CM extrudates.
- Incorporation of the WPC is necessary for extrudates enrichment.
- Statistical analysis shown that WAI and WSI were significantly influenced with FMC and WPC intake changes and their interactions.

Acknowledgment

This work was conducted and financially supported with the agreement of two projects: “JEZGRA” – Development centre for chemical and biochemical engineering and scientific project “Mechanism of the controlled degradation of the carbohydrates with extrusion process (Croatian Ministry of Science). Authors expressed their gratitude.

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