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Development of Low Cost Multipurpose Instant Mix by Extrusion Process using Response Surface Methodology

Food Science

KEYWORDS : - Extrusion, multipurpose, rice, mungbean, groundnut

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ABSTRACT

The purpose of this study was to develop extrusion based multipurpose instant mix. A blend of rice, mungbean and groundnut was used in the study. The blend was extruded at different moisture content (12.6-19.4%), screw speed (349-601 rpm) and barrel temperature (116 -184°C). The regression models for SME, expansion ratio, bulk density, WAI and WSI were highly significant. Feed moisture and barrel temperature had significant effect on all the dependent variables although the effect of screw speed was observed to be the least. Numerical optimization was performed to obtain minimum density and maximum expansion and WAI. Range of predicted values of density, expansion and WAI were used for graphical optimization. Best extrusion conditions were 14 to 15.09% moisture 491 to 550 rpm screw speed and 155 to 175 o C temperature. A multipurpose instant mix was prepared by blending grain mix with milk powder and sugar. The product was compared with the similar products available in the market. It was similar in composition and was cheaper.

INTRODUCTION

A simple, convenient, easy and quick to prepare food product besides being hygienic, free from microbial contamination and also convenient to eat is 'Instant food' (Tamlurkar, 2006).With a growth rate of 12-15 % per year, this food market is gaining general acceptance throughout the globe. (Prescha et al. 2012). A fast-paced urban lifestyle, increasing prevalence of nuclear family structure, rising disposable income, increasingly larger number of globe-trotting consumers with an experimentative palate are all favorable demographic factors spurring the adoption of instant food. This has obviously presented a huge opportunity for the food industry to develop and market convenience food products (Barbut, 2012). Instant foods are prepared from almost all available food grains, either alone or supplemented with fruits, vegetables, legumes, oilseeds, flavouring agents, coloring agents, preservatives, etc. Various technologies are being used to develop "Instant foods" and extrusion is an important technology for processing grain-based products and adds immense value to raw material ranging from corn, wheat and rice to sorghum, oats and soybeans.

Low cost and nutritious instant foods may be developed using major crops in the country which may be blended or supplemented with each other to provide complete nutrition. Processing of blends of cereals with legumes and oilseeds into forms which combine the advantage of nutritive value and convenience of use stands a better chance of success. Extrusion is most economical in large scale production (Onyango et al., 2004). During extrusion, protein gets denatured and the antinutritional factors such as trypsin-inhibitors and haemaglutinins get degraded and microorganisms are killed, so overall digestibility and acceptability of product is enhanced (Mouquet et al., 2003).

Rice is among the major cereal crops of the India. Paddy production is recorded to be 94.11 MT during the year 2010-11. Broken rice is a byproduct of paddy shelling industry and has low saleabilty but composition is similar to white rice. It can serve as a very good base for production of instant low cost food products. Legumes are good and relatively cheap sources of protein for developing countries like India. India is the largest producer of mungbean (Vigna radiata) and is 3rd most important pulse crop of India (Choudhary et al., 2011). Being rich in quality proteins, minerals and vitamins, mungbean is an inseparable ingredient in the diets of vast majority of population in the Indian subcontinent (Singh and Singh 2011). For a complete food, fat requirements are also to be met. Groundnut is the major oilseed of India accounting for around 25 per cent of the total oilseed production of our country. The annual production of groundnut is 7 MT. Thus, cereals, legumes and oilseeds in combination are expected to provide wholesome food providing maximum nutritional requirements. Hence, research was carried out in extrusion cooking of combinations of rice, mung bean and groundnut which could complement each other and result in a nutritionally balanced food.

MATERIAL AND METHODS

Sample preparation

Rice brokens were procured from the local market. Mung bean (var.SML 668) and groundnut pods (var. SG 99) were procured from Department of Plant breeding, PAU, Ludhiana, India. Rice and mungbean were ground to pass through 200 µ sieve using lab mill (Perten Instruments, Sweden). Red skin of roasted groundnuts were removed after decortication. During preliminary trials, composition of the blend and sensory quality was used as criteria for selection of proportion of each food grain. The rice flour, mungbean flour and groundnut flour were blended in the ratio of 76.5:13.5:10 for 15 minutes to ensure uniform mixing in a ribbon blender (G L Extrusion systems, New Delhi, India). The blended grain flour had 10.60% moisture, 10.72% protein, 5.50% fat, 1.27% fibre, 1.97% ash and 69.80% carbohydrates.

Experimental design

Statistical software Design-Expert 8 (Stat-Ease Inc, Minneapolis, MN, USA) was used to design the experiment. The central composite rotatable design for the three independent variables was performed. Dependent variables were specific mechanical energy (SME), expansion ratio, density (D), water absorption index (WAI) and water solubility index (WSI). Response surface methodology was used to investigate the effect of extrusion condition on the product responses. The independent variable levels like feed moisture content (12.6-19.4%), screw speed (349-601 rpm) and barrel temperature of the last zone (108-192°C) considered for study were selected on the basis of the results of earlier experiments. The design required 20 experimental runs with eight factorial points, six star corner points and six centre points.

Extruder and processing conditions

Extrusion was performed on a co-rotating and intermeshing twin-screw extruder Model BC 21 (Clextral, Firminy, France). The barrel diameter and its length to diameter ratio (L/D) were 2.5 mm and 16:1, respectively. The extruder had 4 barrel zones. Temperature of the first, second and third zone were maintained at 40, 70 and 100oC respectively, throughout the experiments, while the temperature at last zone (compression and die section) was varied according to the experimental design. The diameter of die opening was 6 mm. The extruder was powered by 8.5 KW motor with speed variable from 0 to 682 rpm. Raw material was metered into the extruder with a single screw volumetric feeder (D.S. and M, Modena, Italy). A variable speed die face cutter with four bladed knives was used to cut the extrudates.

Determination of product responses
Specific mechanical energy (SME) in Wh/kg was calculated from rated screw speed, motor power rating (8.5 KW),actual screw speed, % motor torque and mass flow rate (kg/h) using the method given by Pansawat et al., 2008. The ratio of the diameter of the extrudate and the diameter of the die was used to express the expansion of the extrudate (Fan et al., 1996). Density (g/cc) of extrudates was determined by a volumetric displacement procedure as described by Patil et al., (2007). WAI and WSI were determined according to the method developed for cereals (Anderson et al., 1969; Yagci and Gogus, 2008; Stojceska et al., 2008).

Statistical analysis and optimization
Responses were subjected to regression analysis in order to assess the effects of moisture content, screw speed and temperature. Second order polynomial regression models were established for the dependent variables to fit experimental data for each response using statistical software Design-Expert 8 (Stat-Ease Inc, Minneapolis, MN, USA).

$$y_i = b_0 + \sum_{i=1}^{3} b_i x_i + \sum_{i=1}^{3} b_{ii} x_i^2 + \sum_{i=1}^{3}\sum_{j=1}^{3} b_{ij} x_i x_j \quad (5)$$

Where xi (i=1, 2, 3) are independent variables (Moisture, screw speed and temperature) respectively, and bo, bi, bii and bij are coefficient for intercept, linear quadratic and interactive effects respectively. Data was analyzed by multiple regression analysis and statistical significance of the terms was examined by analysis of variance (ANOVA) for each response. The adequacy of regression model was checked by correlation coefficients. The lack of fit test was used to judge the adequacy of model fit. To aid visualization of variation in responses with respect to processing variables, series of contour plots were drawn. Numerical optimization was performed to obtain minimum density and maximum expansion and WAI. Range of predicted values of density, expansion and WAI were used for graphical optimization.

RESULTS AND DISCUSSION
The data on values of physical properties of extrudates is presented in Table 1. Results of analysis of variance and regression coefficients are shown in Table 2 & 3 respectively. The regression models for SME, expansion ratio, bulk density, WAI and WSI were highly significant (P < 0.0001), with a high correlation coefficient (R2 = 0.97, 0.97, 0.94, 0.98 and 0.91 respectively). None of the models showed significant lack of fit (P > 0.01), indicating that all the second-order polynomial models correlated well with the measured data. The predicted R-square was found in reasonable agreement with the adjusted R-square for all the parameters. Adequate precision (signal to noise ratio) greater than 4 is desirable. All the parameters showed high adequate precision (Table 2). Results and observations with respect to the relationship of independent variable with individual dependent variable are being presented as follows:

Specific mechanical energy (SME)
The amount of mechanical energy delivered to the extruded material plays an important role in starch conversion. Higher SME usually results in greater degree of starch gelatinization and extrudate expansion. Hence, increased SME is desired for expanding products. Any variable affecting the viscosity of the food melt in the extruder would correspondingly affect SME (Akdogan, 1996).Moisture, screw speed and barrel temperature had significant linear effects on SME (P < 0.01). As expected, SME decreased with increasing moisture and barrel temperature. The calculated SME values ranged from 33.03 to 98.99 Wh/kg (Table 1).

Table 1: Effect of Extrusion condition on process and productresponses

Extrusion Conditions			Responses				
A: Moisture (%)	B:Screw speed (rpm)	C: Temperature (°C)	SME (Wh/ Kg)	Expansion Ratio	Density (g/cm³)	WAI (g/g)	WSI (%)
14	400	125	95.32	2.76	0.218	4.6	17.05
18	400	125	45.19	2.42	0.371	4.44	13.52
14	550	125	98.99	2.85	0.198	4.74	19.54
18	550	125	42.26	2.36	0.431	4.49	15.11
14	400	175	57.45	2.78	0.188	4.92	18.56
18	400	175	41.65	2.54	0.289	5.12	18.12
14	550	175	80.38	3.11	0.176	4.93	19.76
18	550	175	69.62	2.58	0.295	4.98	18.48
12.6	475	150	85.38	3.03	0.189	4.84	17.16
19.4	475	150	33.03	2.29	0.456	4.88	12.32
16	349	150	52.47	2.55	0.225	4.74	17.14
16	601	150	77.57	2.75	0.218	4.82	19.66
16	475	108	73.92	2.5	0.343	4.36	14.32
16	475	192	57.48	2.71	0.215	5.01	18.99
16	475	150	54.56	2.77	0.199	4.69	15.98
16	475	150	51.45	2.79	0.295	4.72	15.44
16	475	150	57.44	2.7	0.217	4.6	16.95
16	475	150	55.31	2.81	0.192	4.71	18.12
16	475	150	57.47	2.68	0.216	4.73	16.13
16	475	150	43.89	2.75	0.217	4.66	17.03

The negative coefficients of the linear terms of moisture and temperature level indicated that SME decreases with increase of these variables, while positive coefficients for screw speed (Table 2) indicated that SME increases with increase in screw speed. The interaction of feed moisture and temperature (Fig: 1), and; screw speed and temperature had positive impact on SME (Table 3).

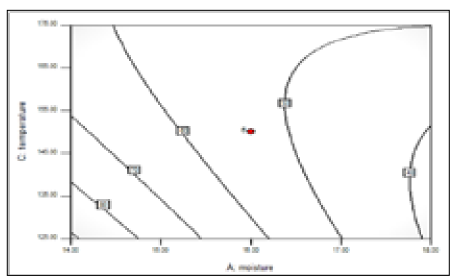


Fig 1: Contour plot showing the effect of Temperature and moisture on SME

The specific mechanical energy (SME) was used by Meuser and van Lengerich (1992) as a system parameter to model extrudate properties. A lubricating effect is produced by high moisture resulting in less energy use and subsequently reduced SME. It increased proportionally with the screw speed, as high screw speed results in higher shear which gives higher SME. Similar results were observed by Ryu and Ng (2001) and Altan et al., (2008) in rice, corn and barley extrudates.

Table 2: ANOVA and model statistics for the dependent variables

Factors	SME (Wh/ Kg)	Expansion Ratio	Density (g/cc)	WAI (g/g)	WSI (%)
F value	39.14	36.21	17.91	45.11	10.84
P > F	0.0001	0.0001	0.0001	0.0001	0.0004
Mean	61.54	2.69	0.26	4.75	16.97
Standard deviation	4.22	0.049	0.028	0.042	0.87

C.V.	6.85	1.82	10.78	0.88	5.12
R- Square	0.9724	0.9702	0.9416	0.9760	0.9071
Adjusted R - Square	0.9476	0.9434	0.8890	0.9543	0.8234
Predicted R – Square	0.9126	0.8693	0.8700	0.9163	0.6417
Adequate precision	21.311	21.836	14.450	26.147	11.678
Lack of fit	0.8658	0.5762	0.9799	0.7792	0.6740

Higher temperature facilitates the transformation from solid flow to viscoelastic flow and reduces the melt viscosity, which resulted in decrease in SME. Similar finding were reported by Dogan and Karwe (2003). The SME values were lower than those observed for extrusion cooking of cereals, which is most likely due to feed composition (Ilo et al., 1996; Jin et al., 1994; Sigh and Smith, 1997).

Expansion Ratio and density

The expansion ratio of extrudates varied between 2.29 and 3.11 where as density of extrudates varied between 0.176 and 0.456 g/cm3 (Table 1). The heat developed during extrusion can increase the temperature of the moisture above the boiling point so that when the extrudate exits from the die, a part of the moisture would quickly flash off as steam and results in an expanded structure with large alveoli and low density. The expansion ratio increases significantly with decrease in feed moisture content and increase in screw speed and barrel temperature. However, the effect of the independent variables on expansion ratio was opposite as that of density. For expansion ratio, the interaction between feed moisture and screw speed ($P<0.01$) ; and screw speed and temperature had positive correlation with density ($P < 0.05$) (Table 3).

Table 3: Regression coefficients for fitted models

Factors	SME (Wh/kg)	Expansion Ratio	Density (g/cc)	WAI (g/g)	WSI (%)
Intercept of Model	53.2744	2.7486	0.222884	4.6851	16.5786
A: Moisture content	-16.2162**	-0.208286**	0.0772534**	-0.00678987	-1.30483**
B: Screw speed	6.87223**	0.0539186**	0.00162757	0.0142451	0.723308
C: Barrel temperature	- 4.416**	0.0712592**	-0.035533**	0.20306**	1.28536**
(Moisture x screw speed) AB	-0.195	-0.055**	0.01225	-0.03	- 0.2175
(Moisture x temperature) AC	10.0375**	0.0075	-0.02075	-0.0825**	0.78
(Screw speed x temperature)BC	6.27**	0.0425*	- 0.00575	-0.04*	-0.315
(Moisture x moisture)A^2	2.58489*	-0.0226528	0.0338789**	0.0612473**	0.466461
(Screw speed x screw speed) B^2	4.64081**	-0.0261884	- 0.00183002	0.0329631*	0.827544**
(Temperature x temperature) C^2	-4.88122**	-0.0420983**	0.0184993*	-0.000624508	0.210593

Feed moisture has been found to be the main factor affecting extrudate density and expansion (Fletcher et al., 1985; Ilo et al., 1999). Feed moisture has an influence on elasticity characteristics of the starch-based material. Increased feed moisture content during extrusion may reduce the elasticity of the dough through plasticization of the melt, resulting in reduced SME and, therefore, reduced gelatinization which results in decreased expansion and increased density of extrudate. Hagenimana et al., (2006) showed that increase in moisture increased the bulk density of rice flour based extrudates.

The decrease in density with increase in screw speed may be attributed to the structural breakdown that might have accompanied high screw speed. Increasing screw speed tends to increase the shearing effect, this caused protein and starch molecules to stretch further apart, weakening bonds and resulting in a puffer product and consequently decreasing density and expanding product (Filli, 2009). This effect has been reported previously (Fletcher et al.,1985; Guha et al. 1997)). An increase in the barrel temperature will increase the degree of superheating of water in the extruder encouraging bubble formation and also a decrease in melt viscosity (Fletcher et al., 1985) leading to reduced density, which was observed in this work. Similar results have been observed by Lawton, Davis and Behnke (1985) and Mercier and Feillet (1975).

Water absorption index (WAI)

WAI values for the extrudates ranged between 4.36 and 5.12 g/g (Table 1). All the independent variables had significant effect on WAI ($P < 0.01$). Increasing moisture significantly decreased WAI. However, increase in screw speed and barrel temperature significantly decreased WAI. WAI measures the water holding by the starch after swelling in excess water, which corresponds to the weight of the gel formed. WAI depends on the availability of hydrophilic groups and on the capacity of gel formation of macro molecule (Gomez and Aguilera, 1983).

WAI has been generally attributed to the dispersion of starch in excess water, which increases by the degree of starch damage due to extrusion- induced fragmentation of amylose and amylopectin (Yagci and Gogus, 2008). As water acts as a plasticizer in the extrusion of starch; it reduces degradation resulting in products with a higher capacity of water absorption. The positive coefficients of the linear terms of screw speed and temperature (Table 3) indicated that WAI increases with increase of these variables. The increase in WAI with screw speed may be attributed to high mechanical shear and higher expansion due to gelatinization. WAI increased with the increase in temperature probably due to increased dextrinization at higher temperature (Kumar et al., 2010). The interaction among feed moisture and temperature ($P< 0.01$); and screw speed and temperature ($P<0.05$) were significant (Fig: 2).

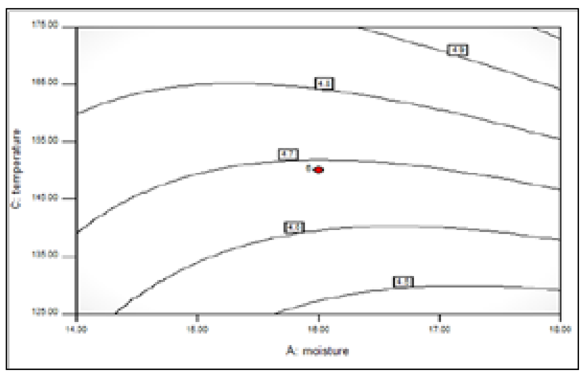


Fig 2: Contour plot showing the effect of temperature and moisture on WAIE

Water solubility index (WSI)

WSI measures the degree of starch conversion during extrusion which is the amount of soluble polysaccharides released from the starch after extrusion (Ding et al., 2006). The WSI values of the extrudates ranged between 12.32 and 19.76 % (Table 1). The WSI was influenced significantly by moisture and barrel temperature ($P < 0.01$). WSI decreased with increase in moisture and screw speed whereas barrel temperature showed a positive correlation with WSI.

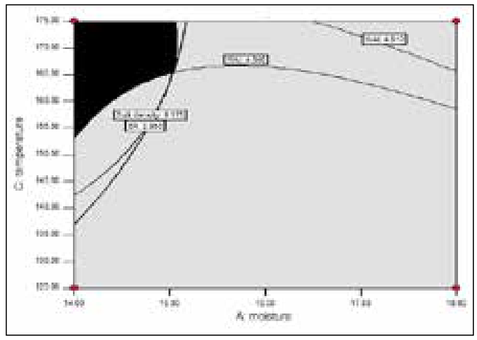
It was found that soluble starch increased with increasing extrusion temperature and decreasing feed moisture (Mercier and Feillet 1975). Higher moisture content in extrusion process can diminish protein denaturation which subsequently lowers WSI values. Badrie and Mellowes (1991) and Hernandez- Diaz et al., (2007) reported similar findings. Generally, solubility increased with increased moisture content and temperature. However, the combination of harsh conditions and low moisture contents caused an increase in the amount of degraded starch granules resulting in an increased formation of water soluble product. This phenomenon is caused by greater shear fragmentation of the starch during extrusion at low moisture contents. WSI is reported to be related to the presence of soluble molecules that have sometimes been attributed to dexterinization (Colonna et al., 1989). Nevertheless the extrusion of non waxy high amylose rice has been reported to have low WSI (Hagenimana et al., 2006)

The high mechanical shear caused breakdown of macromolecules to small molecules with higher solubility. The increase in WSI with increasing screw speed was consistent with the results reported by other researchers Guha et al (1997), Sebio and Chang (2000), Dogan and Karwe (2003). Increasing temperature would increase the degree of starch gelatinization that could increase the amount of soluble starch resulting in an increase in WSI. Positive relationship of WSI and temperature was also achieved by Ding et al., (2005) in extruded products.

Optimization

Numerical optimization provided nine solutions with desirability values varying from 0.81 to 0.88 (Fig: 3). Range of predicted values of expansion (2.95-3.08), density (0.161-0.175) and water absorption index (4.84-4.91) were used for overlay plot graphical optimization. Best extrusion conditions were 14 to 15.09% moisture, 491 to 550 rpm screw speed and 155 to 175 o C temperature.

Fig 3: Overlay plot showing the optimized conditions



The optimized values were used to extrude the mix, which was then ground into powdered form. The mix was then blended with skimmed milk powder and powdered sugar and served with hot milk for sensory evaluation. The level of ingredients was standardized by semi-trained panelists using nine point hedonic scale. Commercially available similar products were analyzed for cost and composition with respect to the developed product. It was concluded that the cost of the multipurpose instant mix was less as compared to the market samples and were similar in composition.

CONCLUSION

RSM revealed the significant effect of all three important extrusion parameters (Screw speed, feed moisture and barrel temperature) on physical properties of twin screw extruded instant grain based instant mix. For maximum expansion, minimum density and maximum WAI, best extrusion conditions were 14 to 15.09% moisture 491 to 550 rpm screw speed and 155 to 175 o C temperature. A multipurpose instant mix was developed by blending grain mix with SMP and sugar. The product was compared with the similar commercially available in the market and it was concluded that a low cost instant product could be obtained from a combination of cereals, pulses and legumes.

REFERENCE

Akdogan, H., (1996) Pressure, torque, energy responses of a twin screw extruder at high moisture contents. Food Research International, 29: 423–429. | Altan, A., McCarthy, K.L. & Maskan, M. (2008) Evaluation of snack foods from barley–tomato pomace blends by extrusion processing. Journal of Food Engineering, 84: 231–242. | Anderson, R. A., Conway H.F., Pfeifer V.F. & Griffin, E.L.(1969) Roll and extrusion cooking of grain sorghum grits. Cereal Science Today, 14: 4-12. | Badrie, N & Mellowes, W.A. (1991) Texture and microstructure of cassava flour extrudate. Journal of Food Science, 56: 1319–1322,1364. | Barbut, S. (2012) Convenience Breaded Poultry Meat Products – New Developments. Trends in Food Science and Technology 26: 14-20. | Choudhary, S., Choudhary, A.K. & Sharma, O.P. (2011) Screening of mung bean(Vigna radiata) genotypes to identify source of resistance to dry root rot. Journal of Food Legumes 24: 117-119. | Colonna, P., Buleon, A. & Mercier, P. (1989) Physically modified starches. In: Starch: properties and potential (edited by T. Galliard) London, John Wiley and Sons, pp 79-114. | Ding, Q., Ainsworth P., Tucker, G. & Marson, H. (2005) The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based expanded snacks. Journal of Food Engineering, 66: 283–289. | Ding, Q., Ainsworth, P., Tucker, G. & Marson, H. (2005) The effect of extrusion conditions on the functional and physical properties of wheat-based expanded snacks. Journal of Food Engineering, 73: 142–148. | Dogan, H. & Karwe, M. V. (2003) Physicochemical properties of Quinoa extrudates. Food Science and Technology International, 9:101–114. | Fan, J., Mitchell, J.R. & Blanchard, J.M.V. (1996) The effect of sugars on the extrusion of maize grits: The role of the glass transition in determining product density and shape. International Journal of Food Science and Technology, 31: 55–65. | Filli, K. B. (2009) Production, optimization and characterization of extruded fura from pearl millet and grain legume flour mixtures. Unpublished PhD Thesis, University of Maiduguri, Maiduguri, Nigeria. | Fletcher, S. I., Richmond, P. & Smith, A. (1985) An experimental study of twin-screw extrusion cooking of maize grits. Journal of Food Engineering, 4: 291-312. | Gomez, M. H. & Aguilera, J.M. (1983) Changes in the starch fraction during extrusion cooking of corn. Journal of Food Science, 48: 378-381. | Guha, M., Ali, Z. S. & Bhattacharya, S. (1997) Twin screw extrusion of rice flour without a die: Effect of brrel temperature and screw speed on extrusion and extrudate characteristics. Journal of Food Engineering, 32: 251-267. | Hagenimana, A., Ding, X. and Fang, T. (2006) Evaluation of rice flour modified by extrusion cooking. Journal of Cereal Science, 43(1): 38-46. | Hernandez-Diaz, J. R., Quintero-Ramos, A., Barnard, J. & Balandran-Quintana, R.R. (2007) Functional properties of extrudates prepared with blends of wheat flour/pinto bean meal with added wheat bran. Food Science and Technology International 13: 301–330. | Ilo, S., Tomschik, U., Berghofer, E. & Mundigler, N. (1996) The Effect of Extrusion Operating Conditions on the Apparent Viscosity and the Properties of Extrudates in Twin-Screw Extrusion Cooking of Maize Grits. Lebensmittel-Wissenschaft und-Technologie, 29 (7): 593–598. | Ilo, S., Liu, Y. & Berghofer, E. (1999) Extrusion cooking of rice flour and amaranth blends. Lebensmittel-Wissenschaft und Technologie, 32: 79-88. | Jin, Z., Hsieh, F. & Huff, H.E. (1994) Extrusion of corn meal with soy fiber, salt, and sugar. Cereal Chemistry 71: 227–234. | Kumar, N., Sarkar, B.C. & Sharma, H.K. (2010) Development and characterization of extruded product of carrot pomace, rice flour and pulse powder. African Journal of Food Science, 4(11): 703 – 717. | Lawton, J. W., Davis, A.B. & Behnke, K.C. (1985) High temperature, short-time extrusion of wheat gluten and bran-like fraction. Cereal Chemistry, 62: 267-269. | Mercier, C. & Feillet, P. (1975) Modification of carbohydrate components by extrusion-cooking of cereal products. Cereal Chemistry, 52: 283–297. | Meuser, F. & Van Lengerich, B. (1992) System analytical model for the extrusion of starches. In: Food Extrusion Science and Technology. J. L. Kokini, C. Ho, & M. V. Larwe (Eds.), (pp. 619–630). New York: Marcel DekkerInc. | Mouquet, C., Salvignol, B., Van Hoan, N., Monvois, J. & Treche, S. (2003) Ability of a “ very low-cost extruder” to produce instant infant flours at a small scale in Vietnam. Food Chemistry 82:8. | Onyango, C., Henle, T., Hoffmann, T. & Bley, T. (2004) Production of high energy density fermented uji using a commercial alpha-amylase or by single-screw extrusion. Lebensm.-Wiss u.-Technol, 37:401–407. | Pansawat, N., Jangchud, K., Jangchud, A., Wuttijumnong, P., Saalia, F.K. & Eitenmiller, R.R. (2008) Effects of extrusion conditions on secondary extrusion variables and physical properties of fish, rice-based snacks. Lebensmittel- Wissenschaft und-Technologie, 41: 632–641. | Patil, R. T., Berrios, J., Tang, D.J. & Swanson, B.G. (2007) Evaluation of methods for expansion properties of legume extrudates. Applied Engineering in Agriculture, 23: 777–783. | Prescha. A., Zablocka-Slowinska, K., Hojka, A., & Grajeta, H. (2012) Instant food products as a source of silicon. Food Chemistry 135: 1756-1761. | Ryu, G.H. & Ng, P.K.W. (2001) Effects of selected process parameters on expansion and mechanical properties of wheat flour and whole cornmeal extrudates. Starch, 53: 147–154. | Sebio L. & Chang, Y.K. (2000) Effect of selected process parameters in extrusion of yam flour (Dioscorea rotundata) on physiochemical properties of extrudates. Nahrang 44: 96-100. | Singh, N. & Smith, A.C. (1997) A comparison of wheat starch, whole wheat meal and oat flour in the extrusion cooking process. Journal of Food Engineering, 34 (1): 15–32. | Singh, D. P. & Singh, B.B. (2011) Breeding for tolerance to abiotic stress in mung bean. Journal of Food Legumes 24: 83-90. | Stojceska, V., Ainsworth, P., Plunkett, A., Ibanoglu, E. & Ibanoglu, S. (2008) Cauliflower by-products as a new source of dietary fibre, antioxidants and proteins in cereal based ready-to-eat expanded snacks. Journal of Food Engineering, 87: 554-563. | Tamlurkar,V. (2006) Role of Instant Foods in the Catering Industry. For: Faculty-Column in www.indianmba.com. | Yagci, S. & Gogus, F. (2008) Response Surface Methodology for Evaluation of Physical and Functional Properties of Extruded Snack Foods Developed from Food – by – Products. Journal of Food Engineering, 86:122–132. |