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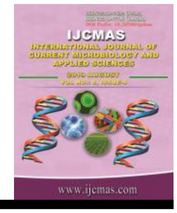

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Effect of Mass Flow Rate, Moisture Content and Machine Parameters on Quality of Extrudates Prepared From Different Blends of Sattu and Kodo

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A B S T R A C T

Extrudates were prepared to identify the optimum machine parameters and prepare good quality ready to eat extruded snacks from a suitable blend of sattu and kodo. Kodo is millet that supply starch necessary to provide required puffing quality to extrudate. Kodo also imparts brightness to the extrudate. Sattu has been blended as it is a rich source of protein gram being the main source followed by wheat and barley. It also provides fibres. The experiments were carried out to find out the effect of different levels of processing parameters. The experiment was planned and conducted to characterize the machine parameters namely screw speed, barrel temperature, and die head temperature and feed parameters namely moisture content and ratio of different blends of two materials namely sattu and kodo identified for preparation of ready to each extruded snack. On analysing the data obtained it was found that the mass flow rate increases with increase in moisture content and the rate of increase is slow at lower values of moisture content which goes on increasing with increase in moisture content also the mass flow rate decreases with decrease in the proportion of kodo in feed.

Introduction

The concept of extrusion cooking has potential to become one of the most promising frontier technologies suitable to prepare good quality engineered food products. Although snack foods were among the first commercially successful extruded foods, today extruders produce many foods of nutritional importance. The ability of extruders to blends diverse ingredients in novel foods can also be exploited in the developing functional foods market. Functional ingredients such as sattu (mixture of roasted gram powder, wheat powder and barley powder in the ratio of 80:10:10) has been taken. Simple single-screw extrusion is relatively more versatile, inexpensive and easy to maintain processes, which can be applied to take advantage of indigenous crops such as cereals, millets and pulses crops. Anti-nutritive compounds can be reduced during extrusion to provide safer and more nutritious foods (Harper 1981; Alonso *et al.,* 2000). Extrusion is the process of pumping thick viscous liquid. The device used for the process is known as extruder. The cooking extruder combines several unit operations- mixing, cooking, kneading, shear, cooling, and/or final shaping/ forming. The combination of operations is possible because of a multitude of controllable variables such as feed rate, total moisture in barrel, screw speed, barrel temperature, screw profile, and die configuration. Extruded food materials undergo various transformations including starch gelatinization, fragmentation and protein denaturation, which affect the properties of the extrudates (Ficarella *et al.*, 2003)

There are basically two types of continuous screw extruders used in the food and pet food business; single-screw and twin-screw. This study was conducted on a single screw extruder. In a single-screw extruder (SSE) the only force that keeps the material rotating with the screw and advancing it ahead is its friction against the inner barrel surface. This fact tends to limit the formulations that can be extruded with a SSE. High-moisture and high-fat formulations may be difficult to extrude with a SSE. However, a low fat containing material can be successfully extruded in SSE. Extrusion cooking combines the heating of food raw material with the act of extrusion to create a cooked and shaped food product. Cooking of food ingredients during the extrusion process results in the gelatinization of starch, denaturation of protein, inactivation of many raw food enzymes responsible for food deterioration during storage, the destruction of naturally occurring toxic substances such as trypsin inhibitors in soybeans, and the diminishing of microbial counts in the final product (Alonso *et al.*, 2000). Humans and other monogastric species cannot easily digest un-gelatinized starch. Extrusion cooking is somewhat unique because gelatinization occurs at much lower moisture levels (12-22%) than necessary in other food processing operations rather processing conditions that increase temperature, shear, and pressure tend to increase the rate of gelatinization. The presence of other food compounds, particularly lipids, sucrose, dietary fibre and salts, also affects gelatinization (Harper 1981).

In the present study it was planned to explore the possibilities of extruding sattu in a single screw extruder, for this purpose one of the minor millet Kodo was taken as base material to provide required puffing as well as colour to the extrudates, black pepper and salt were also added to the blends in different proportions in acceptable range so as to bring the taste and flavor to the extrudates. The quality of extrudates prepared was tasted for its textural as well as sensory quality.

Materials and Methods

A laboratory model single screw extruder (brabender make) was used for preparation of extrudates. A single screw extruder was selected because of its better rigidity, low cost, development of large shear forces and more viscous dissipation of heat over twin screw extruder. The raw materials for this research problem were:

Sattu (in a fixed proportion of 80% of roasted gram powder, and 10% of roasted wheat and barley powder each)

Kodo.

Sattu and Kodo were procured from local market of Jabalpur. After initial removal of foreign materials, all the flour were blended in predetermined proportions and mixed thoroughly in a mixer and then m.c. content of samples determined. Based upon the existing m.c. it was decided to add/remove moisture to obtain desired moisture level. After calculating the required amount of moisture it was added and mixed thoroughly and kept for conditioning after 24hrs the sample was ready for extrusion and they were fed to the Brabender single screw extruder for making the extruded product at different predetermined set of operations.

The blends in different proportion were made as per the experimental plant.

Analysis of the results obtained was done by using Central Composite Rotatable Design of Response Surface Methodology and by developing suitable empirical model and testing their correlation and significance of variables.

Moisture content of raw materials was determined separately for each ingredient by standard oven drying method. Was ground and subjected to drying at 80^{o}C for 16h. The mass of sample before and after drying was recorded by standard method and the loss of mass was for this purpose of sample of grains calculated and then the moisture content was determined by following formula.

$$\text{Moisture content (\%, w.b.)} = \frac{\text{Initial mass of sample (g)} - \text{Final mass of sample (g)}}{\text{Initial mass of sample (g)}} \times 100$$

Control of Moisture content of Blends

Moisture content of blends is an independent parameter, therefore in order to arrive at the predetermine a moisture content of blends, the amount of water present in all the components of blends was determined separately

Moisture Content of the Extrudate (MCE)

Moisture content of extrudates was determined by standard oven dryingmethod.

Mass Flow Rate (MFR)

It is the rate at which the extrudates come out of die, expressed in grams per second. It was measured by collecting the extrudate in polyethylene bags for a specific period of time (usually 20 seconds) as soon as it came out of the extrudater and its weight was taken instantly.

$$\text{Mass Flow Rate (MFR), g/s} = \frac{\text{Mass of sample collected (g)}}{\text{Time taken to collect sample (s)}}$$

Results and Discussion

Mass Flow Rate (MFR) of extrudates

The multiple regression analysis for mass flow rate of extrudates (MCE)versus feed moisture content (MC_F), blend ratio (B_R), barrel temperature (T_{Brl}), die head temperature (T_{Die}) and screw speed (S_S) was done using CCRD and fitting of second degree polynomial equation for representative response surface of data resulted in the development of following model;

$$MFR = -3.21 - 0.13 \times MC_F - 0.09^* \times BR - 0.00 \times T_{brl} + 0.04T_{die} - 0.02xSS + 0.00 \times MC_F \times BR - 0.00MC_F \times T_{brl} + 9.31 \times MC_F \times T_{die} - 0.00 \times MC_F \times SS - 6.05 \times BR \times T_{brl} - 2.07 \times BR \times T_{die} - 2.91 \times BR \times SS - 4.36 \times T_{brl} \times T_{die} + 4.07 \times T_{brl} \times SS + 2.49 \times T_{die} \times SS + 0.00MC_F^2 + 2.92 \times BR^2 + 2.92 \times T_{brl}^2 - 2.03 \times T_{die}^2 - 1.81 \times SS^2 \quad \ldots 4.1$$

The R^2 had a value of 0.7970 for the model. The second order model was adequate in describing the mass flow rate of extrudates. The results of analysis of variance (ANOVA) for model are presented in Table 3.1.

The response surface graphs of the model 3.1 are presented in Fig. 3.1 to 3.10. Response surface graphs as shown in Fig. 3.1, 3.2, 3.3

and 3.4 show the interactive effect of moisture content of feed with blend ratio, barrel temperature, die head temperature and screw speed respectively on the mass flow rate of extrudates. Fig 3.5, 3.6 and 3.7 shows the effect of blend ratio with barrel temperature, die head temperature and screw speed respectively on mass flow rate of extrudates.

Fig. 3.8 and 3.9 show the interactive effect of barrel temperature with die head temperature and screw speed respectively on the mass flow rate of extrudates and Fig. 3.10 shows the response surface graph of die head temperature and screw speed on mass flow rate of extrudates.

As seen in Fig. 3.1 the mass flow rate increases slowly with increase in moisture content and with increase in proportion of sattu in feed. Whereas, the mass flow rate increases very slowly with increase in the barrel temperature of Zone III and temperature of die head assembly (Fig. 3.2 & 3.3). Fig 3.4 exhibits that there is increase in mass flow rate with the increase in screw speed.

It is clear from the graphs that moisture content of feed had vital role over mass flow rate of extrudates. The increase in elevation of contours is towards the higher value of moisture content, which means that as the value of moisture content increases the mass flow rate also increases simultaneously and vice versa. The effect of other parameters did not affect the value significantly. This may be because at higher moisture content the feed had more fluidity.

Moisture content (MCE) of extrudates

The multiple regression analysis for moisture content of extrudates (MCE)versus feed moisture content (MC_F), blend ratio (B_R), barrel temperature (T_{Brl}), die head temperature (T_{Die}) and screw speed (S_S) was done using CCRD and fitting of second degree polynomial equation for representative response surface of data resulted in the development of following model;

$$M.C.E. = -23.09 - 1.30 \times MC_F + 0.16 \times BR + 0.36 \times T_{brl} + 0.27 \times T_{die} - 0.37 \times SS - 0.01 \times MC_F \times BR - 0.00 \times MC_F \times T_{brl} - 0.00 \times MC_F \times T_{die} - 0.00 \times MC_F \times SS - 0.00 \times BR \times T_{brl} + 0.00 \times BR \times T_{die} - 2.02 \times BR \times SS + 0.00 \times T_{brl} \times T_{die} - 8.19 \times T_{brl} \times SS + 0.00 \times T_{die} \times SS + 0.13 \times MC_F^2 + 4.61 \times BR^2 - 0.00 \times T_{brl}^2 - 0.00 \times T_{die}^2 - 2.19 \times SS^2 \ldots 4.2$$

The R^2 had a value of 0.8588 for the model. The brief information results of analysis of variance (ANOVA) for model 3.2 are presented in Table 3.2.

Table.1 Analysis of variance for mass flow rate (MFR) of extrudates

Source	DF	SS	MSS	F	P
Regression	20	1.06	0.05	2.16	**0.09**
Residual	11	0.27	0.02		
Total	**31**	**1.33**	**0.07**		

Table.2 Analysis of variance for moisture content (MCE) of extrudates

Source	DF	SS	MSS	F	P
Regression	20	29.98	1.50	3.35	**0.02**
Residual	11	4.93	0.45		
Total	**31**	**34.91**	**1.95**		

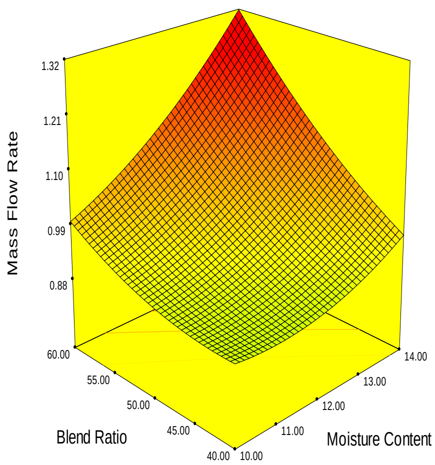

Fig. 3.1 Effect of moisture content and blend ratio on mass flow rate of extrudates

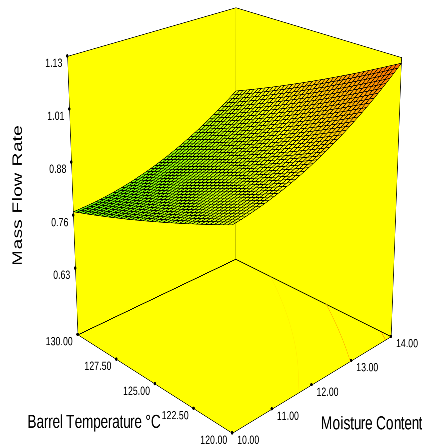

Fig. 3.2 Effect of moisture content and blend ratio on mass flow rate of extrudates

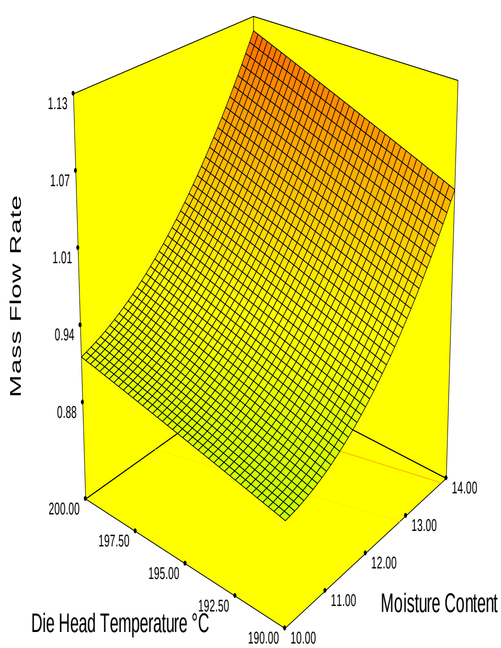

Fig. 3.3 Effect of moisture content and die head temperature on mass flow rate of extrudates

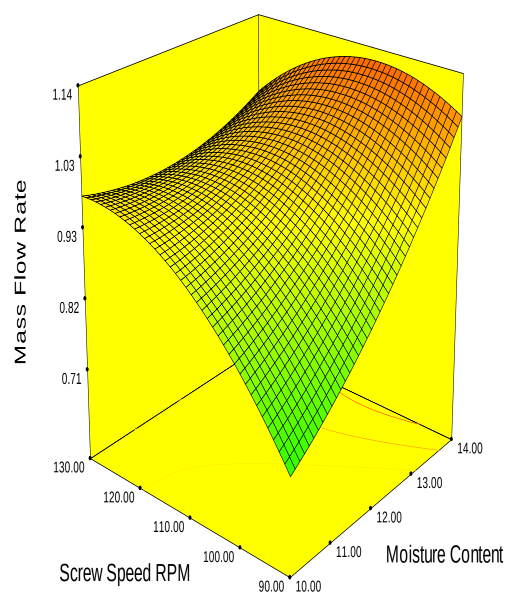

Fig. 3.4 Effect of moisture content and screw speed on mass flow rate of extrudates

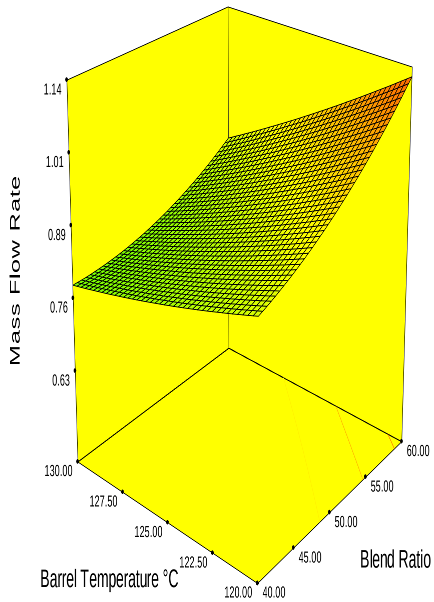

Fig. 3.5 Effect of blend ratio and barrel temper... on mass flow rate of...

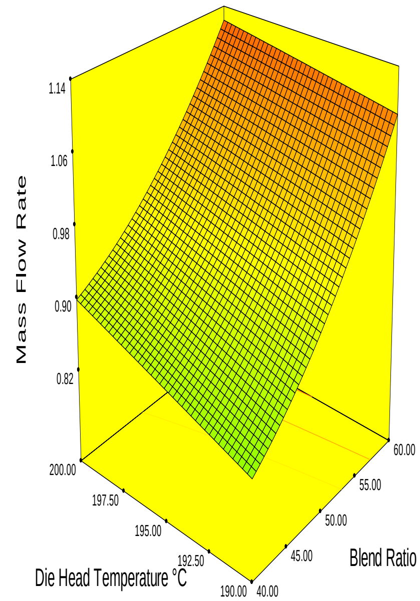

Fig. 3.6 Effect of blend ratio and die head temperature o... rate of extrudates

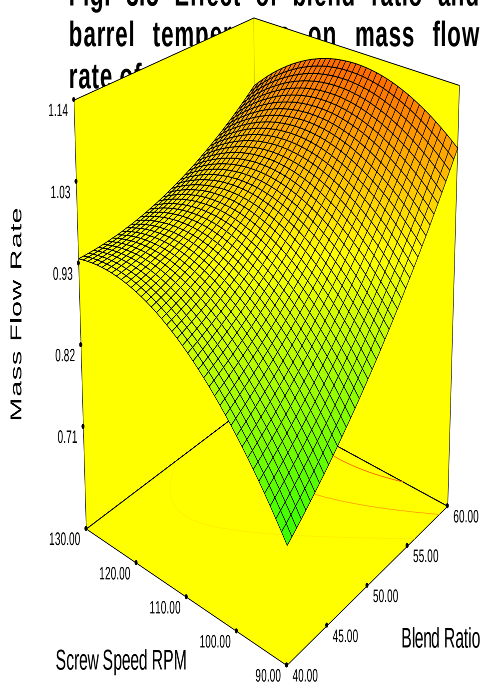

Fig. 3.7 Effect of blend ratio and screw speed on mass flow rate of extrudates

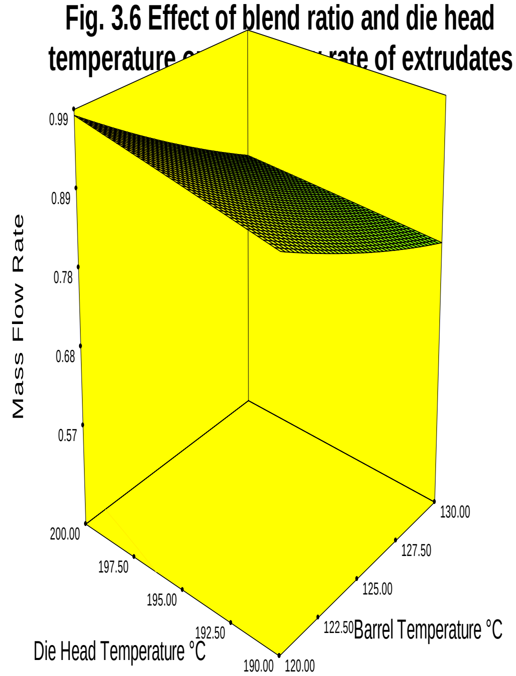

Fig. 3.8 Effect of barrel temperature and die head temperature on mass flow rate of extrudates

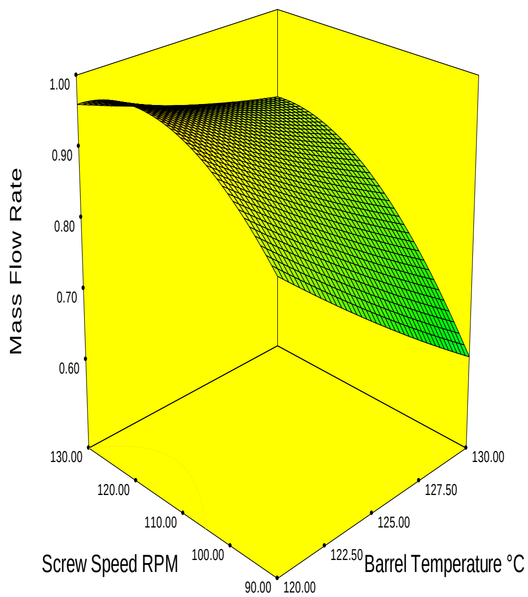

Fig. 3.9 Effect of barrel temperature and screw speed on mass flow rate of extrudates

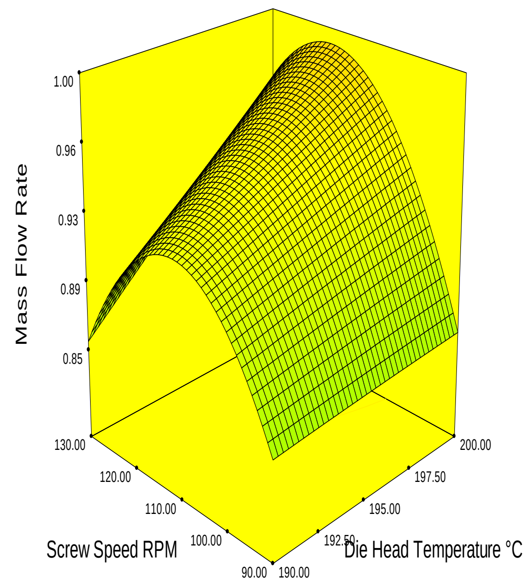

Fig. 3.10 Effect of die head temperature and screw speed on mass flow rate of extrudates

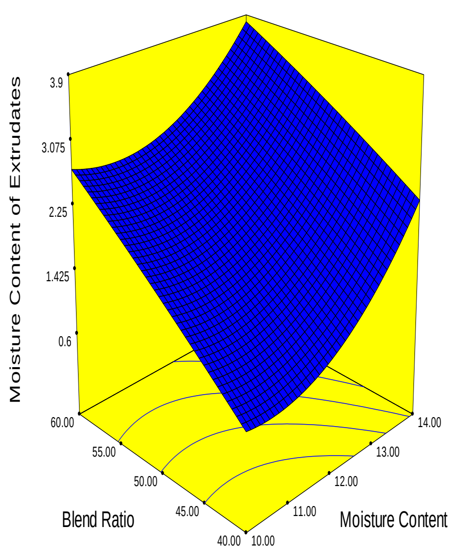

Fig. 3.11 Effect of feed moisture content and blend ratio on moisture content of extrudates

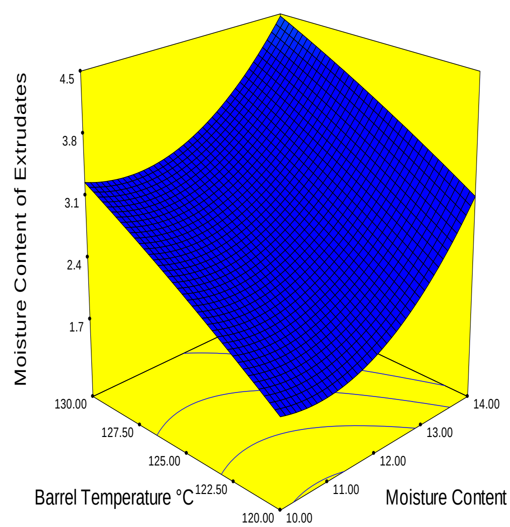

Fig. 3.12 Effect of feed moisture content and barrel temperature on moisture content of extrudates

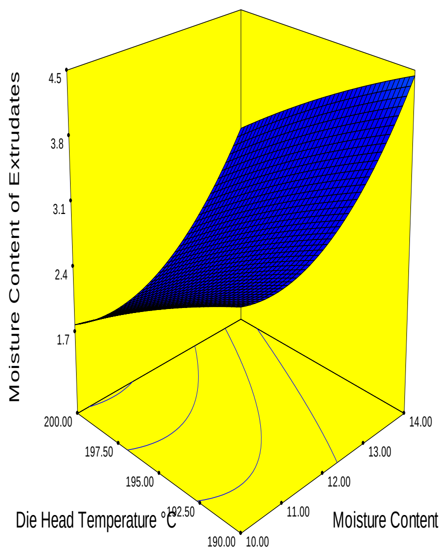

Fig. 3.13 Effect of feed moisture content and die head temperature on moisture content of extrudates

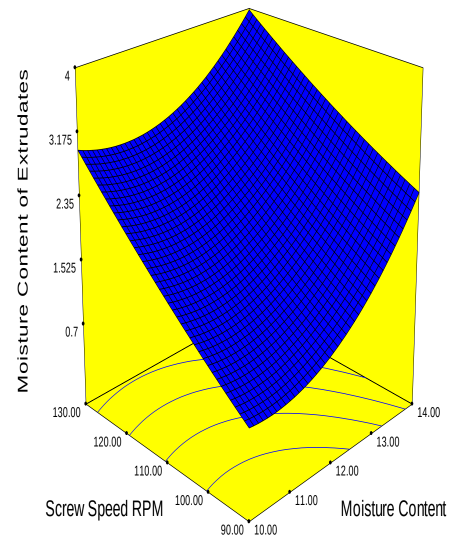

Fig. 3.14 Effect of feed moisture content and screw speed on moisture content of extrudates

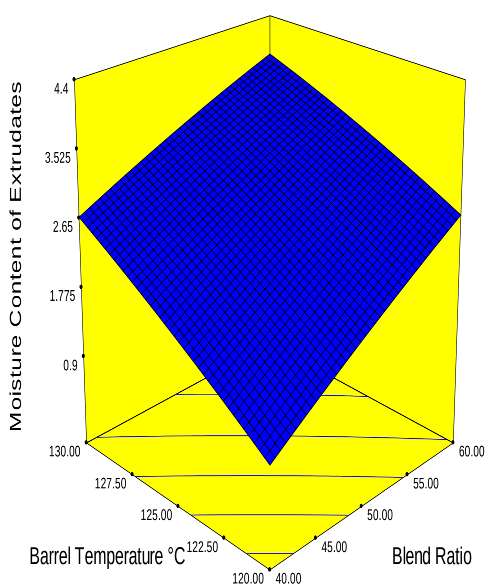

Fig. 3.15 Effect of blend ratio and barrel temperature on moisture content of extrudates

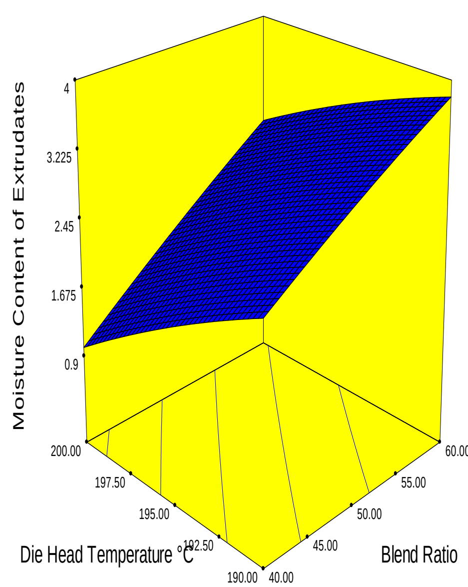

Fig. 3.16Effect of blend ratio and die head temperature on moisture content of extrudates

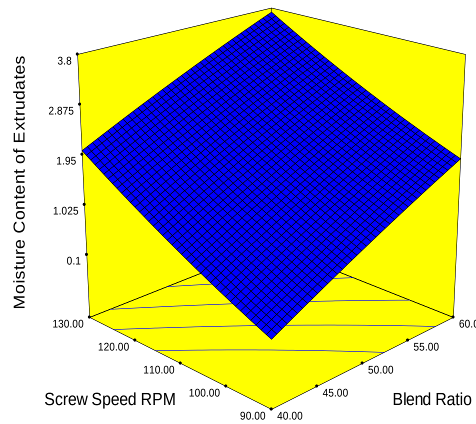

Fig. 3.17 Effect of blend ratio and screw speed on moisture content of extrudates

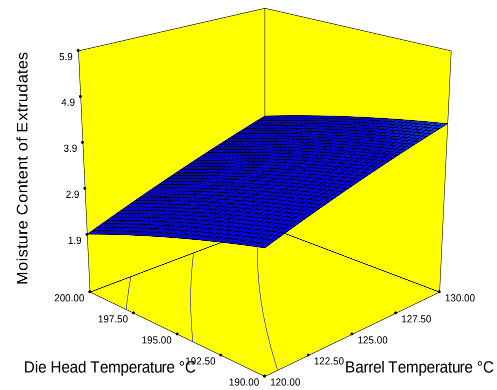

Fig. 3.18 Effect of barrel temperature and die head temperature on moisture content of

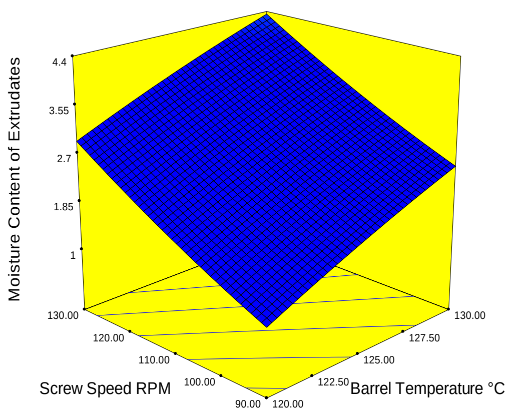

Fig. 3.19 Effect of barrel temperature and screw speed on moisture content of extrudates

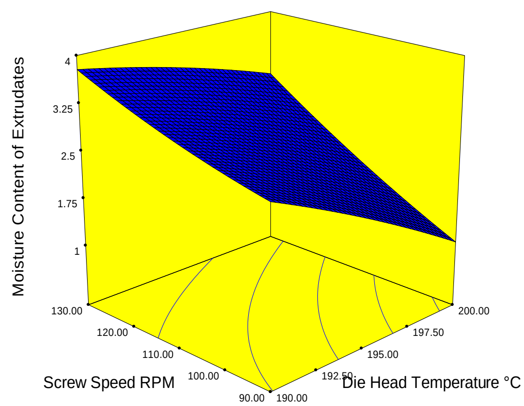

Fig. 3.20 Effect of die head temperature and screw speed on moisture content of extrudates

The F-value 3.35 implies that the model is significant. In this case, linear term of moisture content of feed, interaction term of barrel temperature and die head temperature, quadratic terms of moisture content of feed, blend ratio and barrel temperature are highly influencing variables on the moisture content of extrudates.

The response surface graphs of the model 3.1 are presented in Fig. 3.11 to 3.20. Fig. 3.11, 3.12, 3.13 and 3.14 show the interactive effect of moisture content of feed with blend ratio, barrel temperature, die head temperature and screw speed respectively on the moisture content of extrudates. Fig 3.15, 3.16 and 3.17 show the effect of blend ratio with barrel temperature, die head temperature and screw speed respectively on moisture content of extrudates. Fig. 3.18 and 3.19 show the interactive effect of barrel temperature with die head temperature and screw speed respectively on the moisture content of extrudates and Fig. 3.20 shows the response of die head temperature and screw speed on moisture content of extrudates.

As it is seen from Fig. 3.11 that with increase in moisture content of feed the moisture content of extrudates also increases, similar is the result with increase in blend ratio. Similarly as it is seen from Fig. 3.12, 3.13 and 3.14 that for the increase in barrel temperature, there is increase in MCI, however there is no change when there is variation in die head temperature. It is also depicted from graph that there is a positive correlation between the moisture content of feed and moisture content of extrudate. At the lower value of moisture content of feed (MC_F) and blend ratio, the value of moisture content of extrudate was lowest and when the value of blend ratio increases gradually keeping moisture content of extrudate at constant level, the value of moisture content of extrudate increases up to a certain limit beyond which it decreases. Similarly when the value of moisture content of feed increases keeping blend ratio at constant level, the value of moisture content of extrudate also increases.

Fig. 3.15 shows the combined effect of blend ratio and barrel temperature on the moisture content of extrudate (MCE) as in both cases the MCE increases. The graph shows that the contours are spreading in outward direction, which means that the highest value of moisture content of extrudate, lies nearly at the centre and moving either side will reduce the value. The same trend had not been observed in Fig. 3.16 and 3.17 but has similar effects as of Fig 3.15. This may be due to the reason that various blends must be having different levels of bound moisture.

Figure 3.18 shows the effect of barrel temperature and die head temperature on the moisture content of extrudates, which clearly shows that by decreasing the value of barrel temperature and increasing the value of die head temperature, the value of moisture content of extrudate decreases. At high temperature the moisture of the moving feed evaporates at higher rate.

Figure 3.19 showed the relationship of barrel temperature and screw speed on the moisture content of extrudate. The effect of screw speed on moisture content of extrudate was found to be increasing because the highest point of moisture content of extrudate lies at lower end of screw speed 110 rpm and 120°C barrel temperature. By keeping 120°C barrel temperature as constant and increasing the value of screw speed, the value of moisture content of extrudate was increasing. As the value of barrel temperature increases to 130°C, the moisture content of extrudate alsoincreases in an effective way.

The Fig. 3.20 shows that by increasing the value of die head temperature the value of moisture content of extrudate decreases but by increasing the screw speed, the moisture content of extrudates increases sharply. Thus screw speed affects more in comparison to die head temperature on moisture content of extrudate.

References

Alonso (2000). Effects of extrusion and traditional processing methods on anti-nutrients and in vitro digestibility of protein and starch in faba and kidney beans. Food chemistry, 68 (2): 159-165.

Ficarella A., Milanese M. and Laforgia D. (2003). Numerical simulation of cereal extrusion and influence of design and process on the final quality. Tecnica-Molitoria (Italy), Jan 2003. 54(1) pp. 9-24.

Harper J.M. (1981).Extrusion of Foods, Boca Raton, FL, CRC Press, Inc.

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