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Research Article

Influence of Oil on Extrusion Cooking Process of Maize Semolina in a Twin Screw Extruder

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Abstract: Aim of this study is to determine the effect of oil on the extrusion cooking process. Editable oils are often desired in extruded snacks to improve their eating quality. But the incorporation of oil into the extrusion process causes considerable changes in the expansion of the extruded products until it inhibits expansion in higher concentrations. In order to specify the effects of oil on the extrusion cooking process, in this study maize semolina with different oil contents (0, 2, 4, 5 and 6%, respectively) were expanded in a co-rotating twin screw extruder. Oil was applied to the maize semolina prior to the extrusion process. Diameter of the extrudates and pressure in the extruder were measured for each oil contents in order to determine the effect of oil content on these parameters. With increasing oil content, the change of diameter constantly increased. Pressure increased slightly at low oil contents but dropped significantly at higher oil contents. In this setup extrusion was feasible up to 4% oil content without a loss of the diameter of the extrudates and up to 6% of oil with increasing variabilities in the diameter of the extrudates and in the process pressure.

Keywords: Expansion, extrusion cooking, maize semolina, oil content, pressure, twin screw extruder

INTRODUCTION

Extrusion cooking of starch based matrices is a current method in the snack production. Key parameters in product quality are texture and crispness, which depend on the expansion of molten starch during extrusion cooking (Horvat *et al*., 2013). A modification of extruder operating variables results in changes in the physical and chemical properties of the extrudates (Onwulata *et al*., 1994; Bhattacharya and Hanna, 1987).

In food and feed processing oils are often desired in extruded products in order to improve their eating quality (Moraru and Kokini, 2003; Ilo *et al*., 2000). Particularly elderly people with low appetite are often at risk for malnutrition (Chen and Rosenthal, 2015). So it is important that diets for the elderly should have increased energy density and should be served in small portions like oil enriched extruded snacks. The incorporation of oil into extruded products is announced to considerably change the expansion.

During hot extrusion of corn semolina carbohydrates gelatinize and expand under pressure and temperature. The shear forces at the extruder screw lead to an increase in temperature and pressure forming (Horvat *et al*., 2013). The study of Bhattacharya and Hanna (1988) shows that shear forces on the extrudates increased when oil concentration decreased from 3, 9% to 1, 8%. Oils can thereby interfere with the extrusion cooking process since they reduce temperature and pressure through a lubricating effect. Due to an increase of lubrication, the starch molecules can be subjected to less mechanical stress during extrusion processing (Horvat *et al*., 2013). Increasing the oil content considerably decreased the degree of starch gelatinization of the extrudates (Lin *et al*., 1997). Reduced starch gelatinization finally leads to decreased expansion (Moraru and Kokini, 2003).

Those examples show that extrusion expansion is relatively well addressed in literature, but most of the available studies are not focusing on the effect of the limit of oil during the extrusion process. No study was found in which oil was applied to the maize semolina prior to the extrusion process. This creates a need for studies and publications in this field. Therefore, the aim of this study is to examine the influence of vegetable oil content on the expansion behavior of molten maize semolina and identifies the maximum oil content, wherein the extrusion is still possible.

MATERIALS AND METHODS

Material: Commercially available maize semolina (Maisgrieß Bäko GF 750) with a moisture content of 12% was obtained by CORNEXO GmbH and Co. KG

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Table 1: Moisture content (%) of maize semolina

Batch 1	Batch 2	Batch 3
12,04	12,63	11,87

Fig. 1: Screw profile used for the extrusion cooking process

(Freimersheim, GER). Three batches with almost similar moisture contents were used over the experimental period. Rape oil (Tafelöl, Erfurter Ölmühle W. Fischer GmbH, Erfurt, GER) was used to achieve the desired oil content.

Moisture content of maize semolina was measured thermo-gravimetrically (triple determination) with a Sartorius MA 40 Moisture Analyzer (Sartorius AG Göttingen, GER). 5 g samples were weighed in aluminum scale plates (Rotilabo-Einmal-Wägeschalen, Carl Roth GmbH and Co, Karlsruhe, GER) and dried at 100°C in the Moisture Analyzer. Moisture loss was measured continuously while drying to determine the total moisture content. The moisture contents of the maize semolina are shown in Table 1.

Methods:

Sample preparation: The sample volume was defined as 1000 g. Maize semolina was mixed with rape oil and samples with an oil content of 0, 2, 4, 5 and 6%, respectively of weight of the maize semolina were produced. Rape oil was added with a nebulizer spray bottle for a better distribution followed by continuous stirring for 3 min in a Kitchen-Aid (Classic KS M45, Whirlpool, USA).

Extrusion processing: For the extrusion process a ZSE 18HP-40D co-rotating twin screw extruder (LEISTRITZ Extrusionstechnik GmbH, Nürnberg, GER) was used. The screws showed a diameter of 18 mm and a length to diameter ratio of 40:1. The screws had a continuously transporting profile without any kneading elements (Fig. 1.)

The extruder was equipped with a 2 mm round die. The constant speed of the screws was 600 rotations per second. The maize semolina mixture was fed into the extruder with a FlexWall plus N feeder (Brabender-Technologie KG, Duisburg, GER). To generate a constant supply, the feeder was calibrated beforehand. It was adjusted to maintain a constant flow of 100 g per minute.

The extruder was equipped with seven different heating areas. These were tempered as follows in °C: 25, 40, 60, 70, 80, 100 and 100. The temperatures were initialized by STW 150 temperature control system (SINGLE Temperiertechnik GmbH, Hochdorf, GER). A melt temperature of 140°C was obtained. Melting pressure and melting temperature were measured by sensors (M 30 for pressure and TCM for temperature) from GEFRAN spa (Provaglio D'Iseo, ITA) installed at the die. The machine was programmed to switch off at a pressure of 250 bar. After the extruder had reached the processing temperatures, the screws were moistened by water injection. Then pure maize semolina was fed into the machine until steady-state extrusion conditions were reached so that no visible drifts in temperature and pressure occurred. The first sample of maize semolina (0% oil concentration) had been passing the machine for exactly 3 min when the first cylindrically shaped extruded sample of 20 cm length was collected as it emerged from the die. At the same time melting temperature and the pressure at the extruder die were measured. For the next 3:30 min every 30 sec an extruded sample was taken and pressure and temperature were measured. In this way, all prepared samples passed the extruder from 0% to 6% oil content in ascending order.

Expansion diameters: To evaluate the expansion, the diameters of the maize extrudates were measured with a caliper in three different parts (top, bottom and middle) of the extrudates. Six measurements of each sample expanded maize semolina with each specific oil concentration were performed and the arithmetic mean and the standard deviation were determined.

RESULTS

Effect of oil content on the change of the diameter of the extrudates: The variability of the diameter of the extrudates, described by the standard deviation of the diameters, constantly increased with increasing oil contents as depicted in Fig. 2, which shows the average diameters in mm of the extrudates depending on the oil concentration of the used raw mixture in percent. While the standard deviation of diameter was 0.44 mm for the control (0% of oil addition), it increased to 0.59 mm for the oil content of 4% and leaped to 0.83 mm for the oil content of 5%, almost twice of the deviation of the control (Table 2).

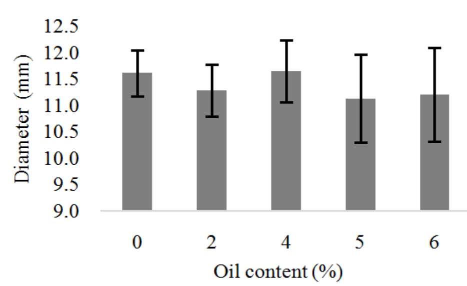

Fig. 2: Effect of oil content (%) on the change of the diameter (mm) of the expanded maize semolina and the increasing standard deviation of the diameters caused by increasing oil concentrations in the semolina

Table 2: Standard deviation of extrudate diameter for different oil contents

Oil content (%)	0	2	4	5	6
Standard deviation of diameter (mm)	0.44	0.49	0.59	0.83	0.89

Table 3: Standard deviation of pressure for different oil contents

Oil content (%)	0	2	4	5	6
Standard deviation of pressure (10^5 Pa)	4.71	4.39	4.39	18.62	39.03

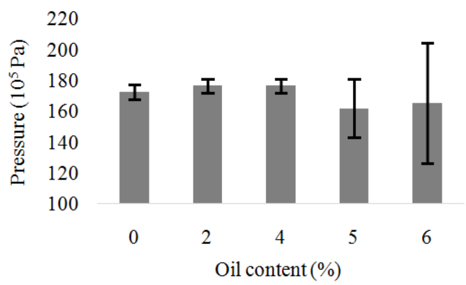

Fig. 3: Effect of oil content (%) on the measured pressure during the expansion process and the increasing standard deviation of the pressure caused by increasing oil concentrations

Effect of oil content on the change of pressure: For the oil contents of 2% and 4% only slight differences in the change of pressure, described by the standard deviation of pressure, where found. For the oil contents of 5% and 6% the variability of pressure increased drastically as illustrated in Fig. 3. This diagram describes the measured pressure on the die of the machine in bar (10^5 Pa) depending on the oil concentration of the used raw material in percent. The change of pressure ranged from 4-5×10^5 Pa for the oil contents of 0, 2 and 4%, respectively whereas it increased markedly to 18.62×10^5 Pa for 5 % up to 39.03×10^5 Pa for 6% oil content (Table 3).

Those results show that maize semolina could be extruded up to an oil content of 6%, but the extrusion process at 6% was discontinuously. Not expanded passages with a very high oil content alternated with expanded passages. This resulted in pressure variations with term very high pressures. This often caused the extruder to stop, since it was programmed to shut down at pressures greater than 250 bar.

DISCUSSION

The results in this study prove that expanding cooking extrusion of maize semolina was possible until 4% (w/w) of oil in the maize semolina without major loss of expansion. Oil concentrations of 5% (w/w) und 6% were also possible with partially good expansion but leads to an increasing variation of the diameter of the expanded maize semolina products, a high standard deviation of process pressure and to a discontinuously production process. The well sized expansion of maize semolina up to 4% or even up to 6% of oil (w/w) was in contradiction to the findings of Horvat *et al*. (2013) who observed a significant decrease in expansion of extruded products affected by oil up to 4%. Ilo *et al*. (2000) and Guy (1994) describes that oils can act as plasticizers or emulsifiers and affect more significantly the texture of the extrudates by changes to the system variables of the processes. This plasticizer rise the flexibility of the food polymer and as a result, melt viscosity decrease (Ilo *et al*., 2000; Singh and Smith, 1999; Wang *et al*., 1993; Willett *et al*., 1994). With increasing oil content, the lubricating effect increases correspondingly this causes the pressure to drop (Onwulata *et al*., 1994; Horvat *et al*., 2013). But the present study proved that this may not be the case until an oil concentration up to 4%.

The stop of expansion at an oil content of 6% (w/w) in the maize semolina could be explained by a limited capacity of the maize semolina to absorb the added oil. Therefore apparently part of the oil was not bound to the maize semolina. It was observed that oil was leaking out of the front section of the extruder at higher oil contents. This oil probably leads to the change of the pressure and finally resulted in the variation of diameter of the expanded maize semolina. Furthermore, it also leads to the passages where high amounts of oil were pressed out of the extruder with not gelatinized maize starch in irregular intervals. Therefore the expansion of the maize semolina did not take place at oil concentration over 6% but in contradiction to that, did well up to 5%.

CONCLUSION

The results in this study prove that expanding cooking extrusion of maize semolina is possible until 4% to 5% (w/w) of oil in the maize semolina without major loss of expansion. Further research needs to be done in order to determine how a change of operating variables would influence these results. Those results could be helpful in order to achieve a desired continuous production process for extruded snacks with considerable high oil contents.

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