Wheat milling fractions as a carrier of sugar beet molasses - physical properties of pellets

R. Čolović[1], Nevena Mišljenović[2], Dušica Ivanov[1], Gordana Koprivica[2], C. Dragomir[3], Lj. Lević[2], Jovanka Lević[1], Slavica Sredanović[1]

[1]Institute for Food Technology, University of Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia; [2]Faculty of Technology, University of Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia; [3]National Research & Development Institute for Animal Biology and Nutrition (IBNA Balotesti), Calea Bucuresti nr. 1, Balotesti, Ilfov, 077015, Romania

SUMMARY

Sugar beet molasses (SBM) is a by-product of sugar refining. SBM should be added in animal feed for ruminants for supplying the rumen with rapidly fermentable energy in the form of sugars, and in feed for non-ruminants as a concentrated energy source. Technological limitations of addition of high viscous liquids in animal feed impose limitations of amounts of added liquids. There is a need for a dry product with high concentration of SBM and with good physical properties. The aim of this experimental study was to investigate suitability of use of wheat milling fractions as a carrier of SBM in pelleted form. Three wheat milling fractions (milled whole wheat grain (WW), wheat feed flour (WF) and wheat middlings (WM)) were used as a carrier, and 0, 3, 6 and 9% (w/w) of SBM is applied on them. Addition of SBM reduced temperature at pellet press (highest temperature was achieved with WW and lowest with WM) and decreased bulk density of pellets, due its lubricating effect. SBM reduced hardness of pellets, which also depended on raw material. Visual inspection of pellets showed that surface of WM pellets with 9 % (w/w) of SBM had leaf structure, while surfaces of pellets made of WW and WF were smooth and without gaps. Particle size distribution of raw materials did not have strong influence on pellet quality. WW and WF could be used as a carrier of 9 % (w/w) of molasses while maximum concentration of molasses which could be applied on WM, in order to produce pellets, is 6 % (w/w).

Key words: pelleting, molasses, wheat milling fractions

INTRODUCTION

SBM is a by-product of sugar refining. It is concentrated viscous liquid with approximately 80% of dry matter and 50% of sucrose. In general, addition of 1 to 2% liquids (e.g. molasses, vegetable oil, etc.) in bulk feed has a good influence on preventing segregation, reducing dust potential and improving throughput (Kirchner, 2010). It is reported that SBM acts as a good binder during pelleting process when added in quantities up to 5% (Thomas et al., 1998, Ševković et al., 1991). However, technological limitations of addition of high viscous liquids in animal feed, such as SBM, impose limitations of amounts of added liquids. On the other hand, from nutritive point of view, SBM should be added in animal feed for ruminants in higher concentration: up to 25-31% in the total diet for dairy cows for increasing total dry matter intake, milk yield and protein yield, up to 40% in total sheep diets as an effective supplement. The role of SBM in ruminant feed is to supply the rumen rapidly fermentable energy in the form of sugars, primarily sucrose which is necessary for the microbial fixation of nitrogen in the rumen. For non-ruminants, SBM should be added up to 5% for growing pigs, 10-15% for finishing pigs and 35% for pregnant sows, as a concentrated energy source (Harland, 1995, McGee et al., 1999).

Animal farms are usually equipped with small mixers, without possibility of fine dosing of SBM. SBM is usually weighted on technical scale and manually added in feed mixture. Such mixtures, with high amount of SBM, are inhomogeneous and samples taken from it are very differing in chemical composition (Đuragić et al., 2008).

There is a need for commercially available dry product with high concentration of SBM for easy dosage in feed mixture. Koprivica et al., 2010, made dehydrated bulk product with more than 30% of SBM. Disadvantage of this product was its mash form, because of low bulk density and moderate flowability. Also, this product was more susceptible to microbial contamination.

Pelleting is a manufacturing process that is commonly used to densify, improve handling characteristics and nutritive and economical value of granular materials (Theerarattananoon et al., 2011). Additionally, pelleting improves microbial stability of the product (Čabarkapa et al., 2010). Pellet quality depends on raw materials that comprising it. Generally, raw protein and pre-gelatinized starch positively affect durability and hardness of pellets. On the other hand, raw fiber, such as cellulose, impairs pellet quality (Thomas et al., 1998, Zimonja and Svihus., 2009, Buchanan et al., 2010).

The aim of this experimental study developed at Institute for Food Technology, Novi Sad, Serbia, was to investigate the suitability of wheat milling fractions as a carrier of molasses in pellets production for animal feeding.

MATERIAL AND METHODS

Three wheat milling fractions were used as a carrier of sugar beet molasses (SBM) in this experiment: milled whole wheat grain (WW), milled at hammer mill with sieve openings' diameter of 4 mm, wheat feed flour (WF) and wheat middlings (WM), provided by a flour and pasta factory “Danubius”, Serbia, by milling with roller mill. Average chemical composition of wheat milling fractions is shown in Table 1.

Table 1 Average chemical composition of wheat milling fractions (Tables AEC, 1987)

Composition	Ingredient concentration (% (w/w))		
	WW	WF	WM
Dry matter	87.0	88.0	88.0
Crude protein	11.5	15.0	15.5
Fat	2.0	3.0	4.5
Crude fiber	2.0	2.0	8.0
Ash	1.5	2.0	4.5
Nitrogen-free extract	70.5	66.0	55.5

SBM used in this study is provided by sugar factory ”Crvenka“, Serbia. Dry matter (DM) content of SBM was 83.5%. Average chemical composition of SBM is shown in Table 2.

Table 2 Average chemical composition of sugar beet molasses (Šušić et al., 1995)

Molasses composition	Ingredient concentration (% (w/w))
Sucrose	51.0
Raffinose	1.0
Invert sugar	0.5
Protein	5.0
Glutamic acid	4.0
Betaine	6.0
Other nitrogen compounds	1.5
Organic acids	1.5
Other organic substances	1.5
Mineral compounds	11.5

SBM was added in wheat milling fractions in concentration of 0, 3, 6 and 9% (w/w). For easier handling and dosing, SBM was preheated at 60°C. Addition of SBM was enabled in double-shaft pedal mixer-steam conditioner, Muyang SLHSJ0.2A, China. Afterwards, the mixture was steam-conditioned, with injection of steam of 2 bar pressure, until it reached temperature of 60°C.

The material was pelleted on flat die pellet press 14-175, Amandus Kahl, Germany (Fig. 1). Die with diameter of openings of 6 mm, and thickness of 48 mm was used (D/L = 1:8). Temperature of pellet press die (T1) and temperature of pellets (T2) were determined by temperature sensors.

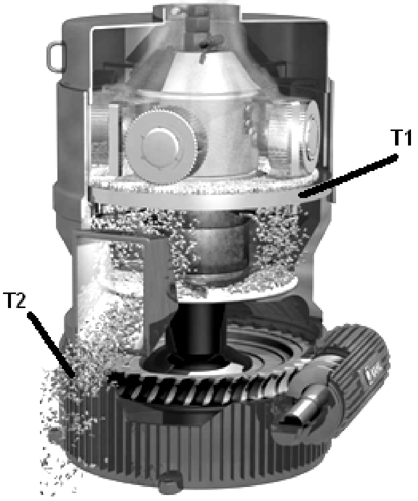


Figure 1 Flat die pellet press.

SBM dry matter content was determined by refractometric analysis with Abbe refractometer, Carl Zeiss Jenna, Germany. Moisture content of dry and conditioned material, and final product was determined by weight loss with oven drying at 105°C (AOAC, 2000).

Granulometric analyse was performed by method of Test sieving (ISO 1591-1 1988 (E)).

Bulk density of pelleted product was measured with bulk density tester (Tonindustrie, West und Goslar, Germany).

Pellet hardness was determined with pellet hardness tester, Amandus Kahl, Germany. Pellet was introduced between the anvil and the piston top of the tester. By manually tightening of pressure screw, static pressure on pellet was increased until pellet burst, and force needed to crack the pellet was determined.

Pellet durability tester according to Pfost, Bühler, Switzerland, was used for determining of durability of pellets. Pellets were placed in rotating drums and pellet fines were induced trough abrasion action of pellets, shearing over each other and over the wall of drums. Durability is expressed as the ratio of the weight tumbling over the weight before tumbling, multiplied with 100, and given as percent.

Statistical Analysis System, STATISTICA 10 (Statistical, USA) was used for analyzing variations (analysis of variance – ANOVA) and least significant differences (LSD). The level of significance was set at $p \leq 0.05$.

RESULTS AND DISCUSSION

Particle size distribution of WW, WF and WM mash is shown in Fig. 2. It could be seen that arithmetic mean diameter (marked with a dashed line) of WW, WF and WM was 930 µm, 650 µm and 340 µm, respectively. Milling with hammer mill (4 mm sieve) was the reason for obtaining large fraction of coarse particles of WW mash, while WF and WM have been by-products from flour production industry for human consumption, which involves usage of roller mills.

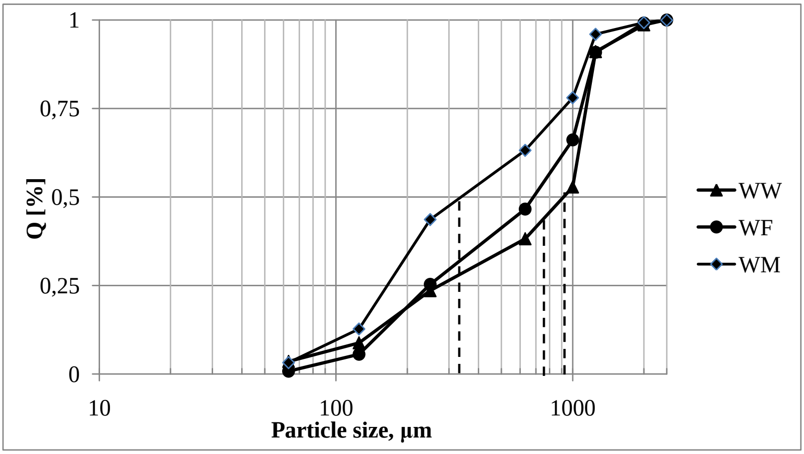


Figure 2 Particle size distribution of wheat milling fractions.
Q = cumulative mass based distribution.

The observation of data included in Table 3 shows that moisture content rises after conditioning process, due to condensation of steam on the surface of material particles. Moisture loss after pelleting process was 1-2 % (w/w), because of evaporation of steam during pressing of material. For each specific mash, moisture content increased with molasses content. This was probably due to lower DM content of molasses. When comparing mashes (mean values) it could be noticed that moisture content of raw WF mash was slightly higher in comparison with WW and WM. After conditioning process, difference in moisture content of different mashes was not higher than 0.5 % (w/w). WF pellets had highest moisture content when measured at the outlet of the pellet press.

Temperature profile during processing of the material is shown in Fig. 3. Addition of molasses decreased friction between material and die channel wall surface, which influenced temperature during processing by decreasing it. Molasses acts as a lubricant due to its specific chemical composition, but also due to the increasing of moisture content of material, which is in correlation with results of Vukmirović et al. 2010. When compare different mashes, it could be seen that highest temperature was achieved with WW, and lowest with WM. This could be connected with chemical composition of different fractions. WW has lower protein content, which could improve binding properties of particles by denaturation (Briggs et al., 1999), but it is also rich in starch which could undergo partial gelatinization (Svihus et al., 2004). These physical changes of material in die holes could cause temperature rise, due to interfering with die surface. On the other hand, WF and WM have higher fat content. Fat has lubricating effect between mash-die interface which causes reduction of the friction and lowers temperature at pellet press (Walter, 1990).

Table 3. Moisture content of the material

Wheat fraction	SBM (%(w/w))	Moisture content of material (% (w/w))		
		Raw	Conditioned	Pelleted
WW	0	13.11 ± 0.18^{a}	17.86 ± 0.20^{a}	16.11 ± 0.21^{a}
	3	13.26 ± 0.28^{a}	18.91 ± 0.20^{bc}	15.88 ± 0.17^{a}
	6	13.40 ± 0.16^{a}	18.51 ± 0.27^{ab}	15.02 ± 0.10^{b}
	9	13.55 ± 0.18^{a}	19.64 ± 0.23^{c}	15.68 ± 0.28^{ab}
	Mean value	13.33	18.73	15.67
WF	0	14.83 ± 0.24^{a}	18.03 ± 0.27^{a}	15.49 ± 0.14^{a}
	3	14.92 ± 0.17^{a}	17.94 ± 0.18^{a}	16.53 ± 0.17^{b}
	6	15.02 ± 0.23^{a}	18.70 ± 0.14^{ab}	17.24 ± 0.25^{bc}
	9	15.12 ± 0.27^{a}	19.22 ± 0.25^{b}	18.04 ± 0.24^{c}
	Mean value	14.97	18.48	16.82
WM	0	12.96 ± 0.13^{a}	17.27 ± 0.20^{a}	16.05 ± 0.14^{a}
	3	13.11 ± 0.25^{a}	18.65 ± 0.28^{bc}	14.96 ± 0.23^{b}
	6	13.30 ± 0.21^{a}	17.96 ± 0.25^{ab}	15.89 ± 0.18^{a}
	9	13.44 ± 0.20^{a}	19.27 ± 0.14^{c}	17.67 ± 0.25^{c}
	Mean value	13.20	18.29	16.14

Results are mean ± Standard deviation; $^{a-c}$Different superscripts within the same column for each fraction indicate significant differences ($p \le 0.05$)

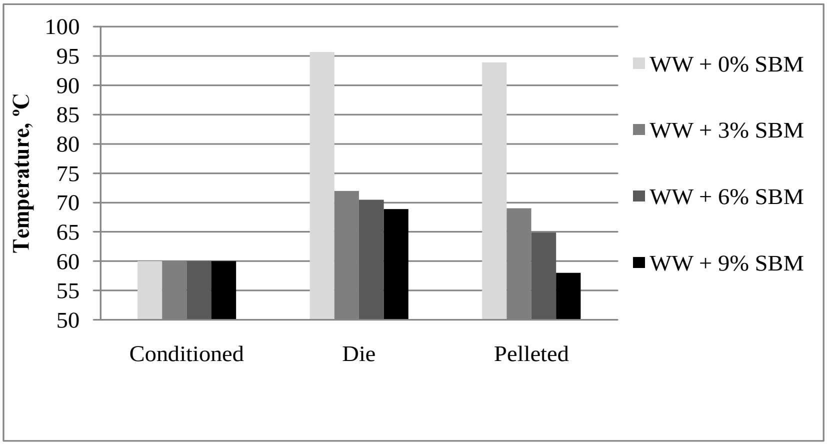
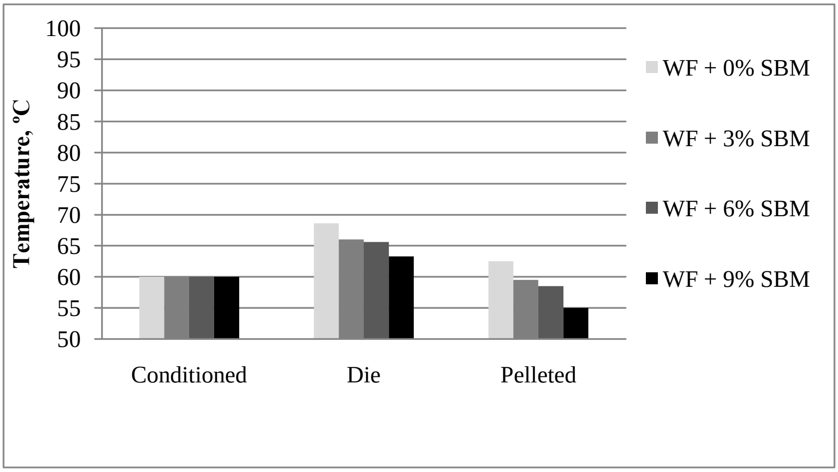


Figure 3 Temperatures during pelleting of wheat milling fractions enriched with SBM



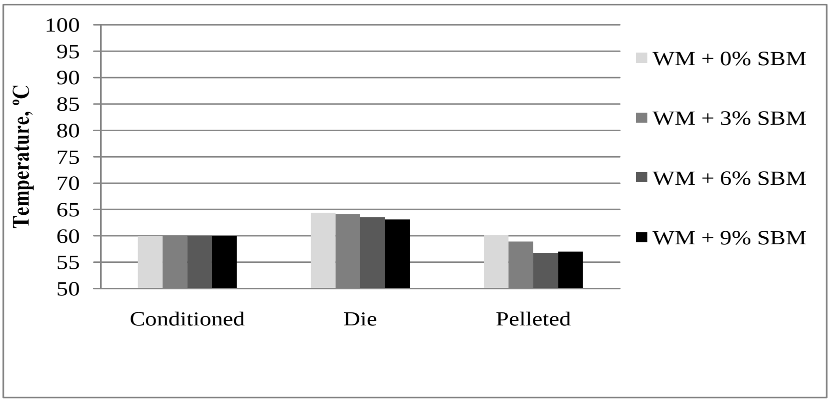


Figure 3. Continued

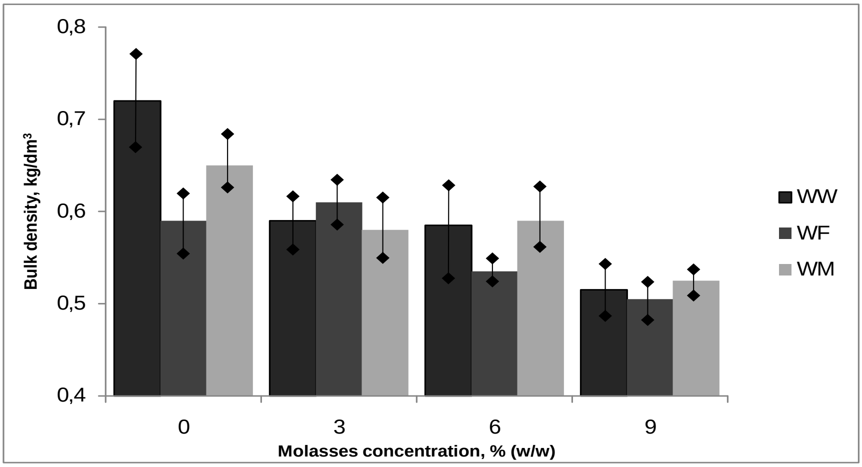


Figure 4. Bulk density of pellets

Fig 4 shows influence of molasses addition on bulk density of pellets. For all three fractions, addition of molasses reduced bulk density of pellets. It was previously stated that compaction was previously stated that of particles pellets depends on friction in die channels (Löwe, 2010). Therefore addition of molasses decreased friction and thus compaction of particles that comprise the pellet.

Results of pellet hardness and durability testing are shown in Table 4. Addition of molasses in material before pelleting reduced hardness of pellets. Pellet hardness of material with 9 % (w/w) of added molasses was significantly ($p \leq 0.05$) reduced and it was approximately 50 % lower in comparison with sample without added molasses. When comparing mean values of hardness for different mashes, the hardest pellets were obtained with WW mash. WW had coarse particles which could induce week spots and thus decrease of hardness of pellets (Stevens, 1987), but also had higher content of starch and lower content of fat, in comparison with WF and WM mash. When looking at the pellet durability results, it could be seen that although statistical analysis has shown significant difference between groups of pellet with different concentration of molasses, results have been differing no more than 0.40 %. Reason for significant difference has been very low standard deviation (no more than 0.05 %). Mean values of durability for different wheat fractions are not differing more than 0.16 %. Durability analysis did not indicate impairing of pellet quality of pelleted WM with 9 % of molasses. Nevertheless, visual inspection of pellets showed that surface of such pellets had leaf structure (see Fig. 5). Surface of WW and WF pellets, even with highest concentration of molasses, was smooth and without gaps, indicating that high fat and crude fiber content, and low starch content impaired binding forces between particles in WM pellets.

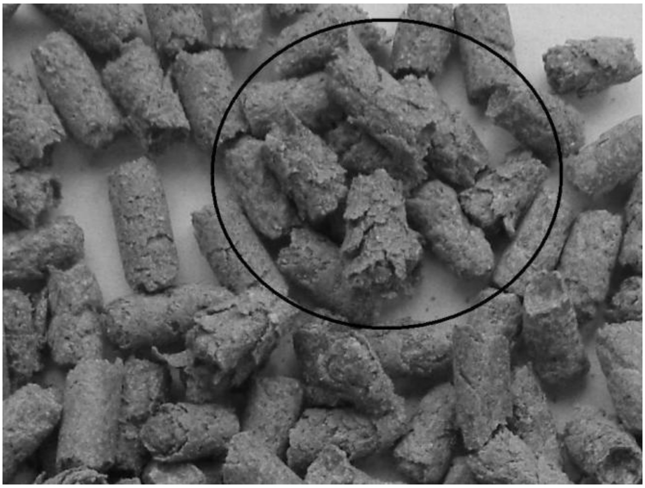


Figure 5. WM pellets with 9 % (w/w) of molasses

Table 4. Hardness and durability of pellets

Wheat fraction	SBM (%(w/w))	Hardness (kg)	Durability (%)
WW	0	22.0 ± 3.80[a]	9.40 ± 0.02[a]
	3	8.32 ± 2.02[b]	8.48 ± 0.02[b]
	6	7.80 ± 2.04[b]	9.49 ± 0.02[b]
	9	7.33 ± 1.53[b]	9.38 ± 0.05[a]
	Mean value	11.36	9.44
WF	0	10.73 ± 1.46[a]	9.49 ± 0.01[a]
	3	8.50 ± 2.31[b]	9.79 ± 0.02[b]
	6	8.19 ± 1.37[b]	9.71 ± 0.02[c]
	9	5.82 ± 0.85[c]	9.40 ± 0.01[d]
	Mean value	8.22	9.60
WM	0	9.24 ± 2.07[a]	9.62 ± 0,02[a]
	3	7.81 ± 1.41[a]	9,75 ± 0.01[b]
	6	7.25 ± 1.09[a]	9.49 ± 0.01[c]
	9	5.07 ± 0.75[b]	9.37 ± 0.02[d]
	Mean value	7.34	9.56

Results are mean ± Standard deviation; [a-d]Different superscripts within the same column for each fraction indicate significant differences ($p \leq 0.05$)

CONCLUSIONS

Temperature of pelleting process depended both on SBM concentration and kind of used wheat material. The highest temperature was detected during pelleting of WW fraction without SBM addition. In opposite, rising concentration of SBM contributed to decrease of pellet pres temperature. It probably shows on lubricating effect of added molasses. Addition of SBM decreased also bulk density of pellets. Addition of molasses decreased bulk density and hardness of pellets, but the effect was depended on kind of raw material. Although durability analysis did not showed that molasses and raw material have influence on pellet quality, visual inspection of pellets showed that surface of WM pellets had leaf structure while surface of WW and WF pellets, even with highest concentration of molasses, was smooth and without gaps, indicating that high fat and crude fiber content, and low starch content impaired binding forces between particles in WM pellets. Particle size distribution of raw materials did not have strong influence on pellet quality. In summary, WW and WF could be used as a carrier of 9 % (w/w) of molasses with good physical quality of pellets. Maximum concentration of molasses which could be applied on WM, in order to produce pellets, is 6 % (w/w).

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