EFFECT OF SCREW CONFIGURATION ON QUALITY AND SME VALUE OF CORN EXTRUDATES

Leszek Mościcki

Agricultural University of Lublin, Poland

Specific mechanical energy consumption (SME) during extrusion-cooking informs us directly about the cost of baro-thermal processing and efficiency of the extruder performance. It is important to understand and interpret the mathematical definition when considering the use of SME for an assessment of the production quality.

$$\mathrm{SME} = \frac{nTM_p}{Q} \ \text{(kWh/kg)} \tag{1}$$

where:

n – per cent screwspeed,
T – per cent torque,
M_p – motor power (kW),
Q – output (kg/h).

In many food extrusion applications, and especially when used in scale-up calculations, the value of SME can remain the same although the product's quality can be quite different [1]. It happens that if the screw speed is increased, the value of torque is reduced because the degree of barrel fill becomes lower. The viscosity of the material may also be reduced because of the increased shear. It means that the value of SME can be the same but the rheology and quality of the product will now be different.

The specific mechanical energy consumption value is recipe dependent. In the extrusion of direct expanded cereals reducing the moisture content will normally increase the value of SME since the torque increases [2, 3].

Replacing the moisture with sufficient amounts of sugar to reduce the torque back to its original value and modifying the overall feed rate to be the same as before will make the texture and sweetness of the product completely different, although the calculated value of SME is the same [1].

A very important role as an extrusion-cooking process characteristic is played by screw geometry, nowadays easily controlled in modern extruders.

A multitude of screw configurations is available to the operator but the normal practice is to configure the screw as a series of repeated conveying and mixing elements (see Fig. 1).

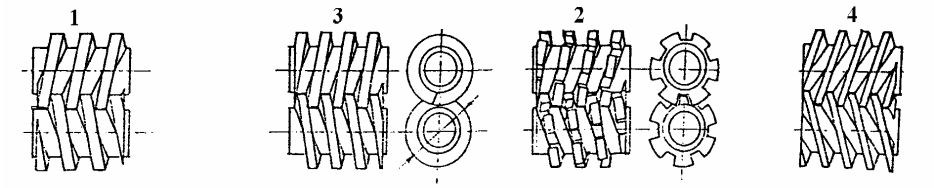

Fig. 1. An example of screws configuration: 1 – feed screw, 2 – mixing elements, 3 – single leadscrew, 4 – double leadscrew

The conveying screws generate the pressure necessary for the material to flow through the mixing restriction which create the biological conversions. The degree of barrel fill cannot be seen visually but information such as torque and pressure differentials provide the symptoms for diagnosing it. Measurements of the number of screws filled and how full they are give an indication of the viscoelastic nature of the material being extruded.

MATERIALS AND METHODS

Effect of process variables and screw configuration on the quality and SME value of direct extrusion corn extrudates has been studied with counter rotating twin screw extruder Valeurex. "Short version" of that extruder has been used during experiments with L/D = 12 (see Fig. 2) and 5 thermal controlled zones [3]. Size of 16 dies was 3 mm round, dimension of the screw = 100 mm. Barrel temperature profile was maintained during the tests in 5 zones: (1) 40°C, (2) 80°C, (3) 120°C, (4) 150°C, (5 – the die head) 120°C.

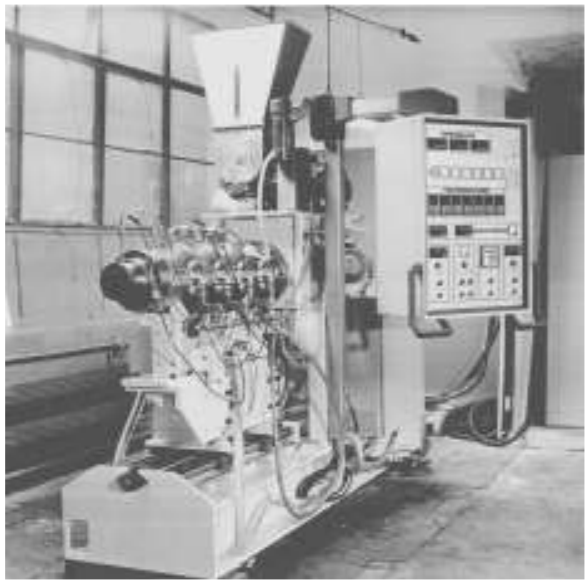

Fig. 2. Valeurex twin – screw extruder

Table 1. Screw configurations used during the tests

Configuration I Low shear	Configuration II High shear
3 D feedscrew 6 × 30° for ward paddles 3 D feedscrew 3 D single leadscrew	3 D feedscrew 3 × 60° forward paddle 2 D feedscrew 2 × 60° forward paddles 2 D single leadscrew 2 × 60° forward paddles 2 × 60° reverse paddles 1 D single leadscrew 2 × 30° reverse paddles

Maize grits (particle size 0.1-0.5 mm) feed rate was fixed to 300 kg/h. Machine variables are presented in table 1.

RESULTS

Results of the measurements are very demonstrative in showing the effect of screw configuration on corn extrudate quality and extrusion-cooking stability (Table 2).

As it was expected, higher torque values were obtained from higher shear configuration II. It was an effect of increased barrel fill however an overall lower viscosity in the last zone (the die head) resulted in a dramatic pressure reduction.

Higher moistures were necessary when using high shear configurations to avoid product burning within the die and an unstable extrusion situation arising. Operators are conscious of this and commonly use higher water/steam addition during the processing, to further reduce die pressures.

Table 2. Effect of screw configuration and process variables on SME and snacks quality

Trial	Screw conguration	Screw speed (rpm)	Water Rate (kg/h)	Die pressure (MPa)	Torque (%)	SME (kWh/kg)	Product die temp. (°C)	Product bulk density (kg/m^3)	Product quality
1	I	120	10	13.0	31	0.116	145	560	bad
2	I	100	10	15.0	44	0.117	149	485	good
3	I	120	4	14.5	36	0.150	152	452	very good
4	I	120	10	13.0	31	0.110	161	499	good
5	I	120	30	13.5	32	0.111	159	512	bad
6	II	120	30	4.5	33	0.109	129	508	bad
7	II	100	30	5.2	40	0.103	131	565	very bad
8	II	120	10	4.0	39	0.135	136	340	very good
9	II	120	30	3.1	30	0.105	139	308	fine
10	II	120	30	3.0	29	0.104	140	320	good

The SME values for a number of trials were the same, however the bulk density and the product's quality were quite different. Although energy consumption is very important from the economic point of view, the final product's quality depends on many other parameters. Extrusion-cooking production has to be based on a certain compromise level. A proper combination of machine vari-

ables as well as good selection of raw material characteristics and process conditions can give desirable results.

CONCLUSIONS

Increasing temperature profiles in the final 3 zones and moistening the material reduce the torque loading by reducing the viscosity of the material within the barrel.

The SME value can not be directly correlated to the product texture and quality. There is more than one process way to produce the same effect.

By proper selection of screw configuration we can create process conditions and biochemical conversions during extrusion-cooking. Controlling transporting, pomping, mixing, compressing and plasticizing of the processed material give us an opportunity to produce high quality extrudates at lower costs.

REFERENCES

1. **Frame N. D.**: The Technology of Extrusion-Cooking, Blackie Academic & Professional, London 1994.
2. **Harper J. M.**: Extrusion of Foods. CRC Press, Florida 1981.
3. **Mościcki L., Juśko S., Mitrus M., Rejak A., Wójtowicz A.**: Results of Valeurex Extrusion-Cooker's Tests. Teka Komisji Motoryzacji i Energetyki Rolnictwa PAN, vol. II, 2002.
4. **Van Zuilichem D. J.**: Extrusion Cooking; Craft or Science? Ph.D. thesis, Wageningen University, The Netherland 1992.

SUMMARY

Effect of process variables and screw configuration on the quality and SME value of direct extrusion corn extrudates has been studied with twin screw, counter rotating extrusion – cooker Valeurex. The obtained results showed that the values of SME for a number of trials were the same although bulk density and product quality were completely different. However, the screw configuration is very important for the creation of the desired process conditions and extrusion-cooking has to be based on the selection of many other parameters (machine variables and raw materials characteristics), which altogether stimulate the proper product's quality and production effectiveness.