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ENERGY ASPECTS IN STORAGE AND PROCESSING IN CEREAL RAW MATERIALS

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The energy requirement during preservation and processing of grain and flour is discussed. Authors draw attention to concentration of grain dryiers and use of solar energy in grain drying as potential sources of energy saving. Proper selection of grain and milling technology may also save energy during grain milling. Breadbaking requires highest demand of energy (65%) in the whole cycle of grain production and utilisation.

INTRODUCTION

The standard of living and well-being of the man-kind depend on adequate supplies of energy. We have become accustomed to oil, coal and natural gas being available in plenty to power the worlds economic growth. The future however, is very uncertain, but there is now wide agreement that world oil supplies can not continue to increase for much more than a decade or so, and may thereafter become increasingly scarce and expensive. This poses a serious and complex problem. The world as a whole will need to turn to other sources of energy, and so despite our present (decreasing) affluence in coal, will also Poland.

The energy shortage should force people not only to search for other than clasical sources of energy but first of all to proper and economical utilization of the tradidional sources. This of course is closely related with proper and economical utilization of energy in order to produce and process maximum quantity of raw materials at the minimum cost of energy. But these two are only possible with excellent understanding of energy requirement of individual steps of the technological processes used.

This is what this conference in all about, as far as food industry is concerned.

ENERGY IN CEREAL STORAGE AND PROCESSING

GRAIN DRYING

In this introductory presentation we would like to discuss briefly the most important (in our view) energy aspects in the field of cereals storage and processing pointing out areas where energy sawing could be found.

Cereals being the most important food and feed raw materials for most of the world population demand special attention and protection during growing, harvesting and storage ass well as during further processing into flour and baked goods. All of these are highly energy consuming operations.

When we talk about cereals we must realize that we are talking about roughly two billion tons of food raw materials, of which half may require drying for safe storage and proper processing.

The most important limitations for proper storage of grain are respiration of grain, insect demage and microbial changes; all leading to deterioration of the grain and grain losses, and all being retarded by low moisture content of the grain. Thus it is obvious that grain drying is one of the most impartant steps required in the production, processing and use sequence of all cereal grains.

Until recently cereal grains were sun dried. With increasing yield, higher moisture content of the grain during harvest and demand for better quality, artificial drying of wheat, corn, oats, barley, rye, etc. has become commonplace. For instance in the USA in 1981 — 75% of the 6.7 billion bushel corn crop was artificially dried [1]. The very wet Polish harvest of 1985 required artificial drying of over 80% of commercially purchased grains [13, 14].

Despite the exclusive worldwide research efforts over the last 25 years the present knowledge of grain drying is as yet insufficient to optimally design each drying process with respect to capacity, grain quality and energy requirements. Future research needs in grain drying fall into a number of categories, each one important for increasing the effectiveness and decreasing the cost of drying process.

Within the 15-20% moisture content range, removing 1% moisture involves drying of about 12.5 kg of water for each ton of dried grain. The theoretical minimum energy to do this is set by the latent heat of vaporation of water which is 2.26 MJ/kg and makes 28.3 MJ/ton. This energy can be provided with no fuel imputby using the sun, but since the combine harvesting about 1 ha/h will deliver 4-6 t of grain/h for drying, artificial drying is normally applied in grain dryiers [7, 9].

Practical energy consumption for removing 1 kg of water (MJ/kg) depends of the type of grain dryier and varies for instance in Poland from about 4.0 to about 16 MJ/kg [15].

More specifie data are presented in Table 1.

Table 1. Energy consumption for removing 1 kg of water by different types of grain dryiers (MJ / kg of water) in Poland [15]

Type of grain dryiers	Energy consumption (MJ/kg of water)
ZSPŻ-8	3.9-5.7
DSP-32	3.9-5.0
SZ-5	4.2-6.0
SZ-20	5.0-16.3
LSO-40	5.0-6.9
LSO-50	5.0-5.9
M-20	6.0
MSZ-3	9.6

As it may be seen from presented data energy consumption by different type of grain dryiers varies widely and no wonder this problem is under constant investigation of grain dryiers designers and grain technologists. The reasons causing different heat requirements by each dryier are complex and are due to various elements.

According to Mühlbauer [11] and Zwingelberg [18] the heat energy in the grain dryier is utilized as follows:

25% of heat is lost in the heat exchanger,
5% „ „ „ „ by radiation into surroundings,
20% „ „ „ „ used for heating the air,
10% „ „ „ „ „ „ „ „ grain,
40% „ „ „ „ „ „ removing water.

According to Lasseran [5, 6] about 50% of heat in the grain dryier is wasted due to the following reasons:

2.5% by poor insulation of the dryier,
2.5% by heating the grain,
11.7% by only partial utilization of air as water carrier,
15.0% by wrong construction of the heat exchanger,
15.8% by lack of utilization of utilization of the waste heat.

The above mentioned losses indicate the directions and action taken to save this energy and have urged the modification of dryiers by:

— proper construction and building of dryiers,
— recilculation of waste heat (saving 15-25% of energy used for drying),
— recirculation of heated grain. According to USHR data [14] about

30% of grain driers operating is the Sowiet Union operate this way giving about 20% of saved energy.

On the other hand the moisture content of grain delivered to grain storages for drying and storage may sometime be as high as 28-30% and thus demanding 2-3-fold drying which is reducing the quality of grain and raising the cost of drying itself.

Thus one of the key problems of proper grain storage and technology is apart from construction also a proper number of grain dryiers and their distribution within the country.

Looking further for energy saving we must turn to solar energy. As it was mentioned above, it is the solar energy which was used for cent uries to dry grain. It is obvious to use this energy which is available all over. Radiation energy of the sun within half on hour amounts to the total energy consumption of all earth for the whole year [8].

Grain drying is a particularly suitable area for using solar energy. It requires only small temperature differences and can be interrupted so, that no energy storage system is needed.

Although solar energy has been known for ages as a drying agent for grain, it wasn't until recently that efforts were made to capture and apply the sun's energy to the drying of grain by the use of solar energy collectors.

Buelow [8] investigated this possiblility in early sixties and presented designs of solar energy collectors for heating air that could be used for drying grain. Due, however, to low cost of energy in these days, his experiments resulted only in very few operations.

However, increased costs of oil has kindled a renewed interest in the potential of applying solar energy to crops drying.

Most of these recent experiments have applied solar energy to low temperature method of drying which dry grain with small temperature rises usually less than 5 °C [12]. Airflow rates established for shelled corn at the air temp. 10 °C is shown in Table 2 [8].

In September and October the relative humidity of the air in the northern hemisphere is about 75-80%. Under this conditions only a 3 °C temperature rise is required to lower the relative humidity of the air

Table 2. Airflow for low temp. drying (shelled corn) [8]

Moisture (%)	Air changes/min.
20	0.8
22	1.0
24	1.6
26	2.4
28	4.0

to 70% which will dry the corn to 15.5% moisture content. Even if the relative humidity is above 90%, the air temperature need be increased only about 6 °C to dry corn to 15.5%.

Recent experminents have shown that solar energy can be collected with relatively simple flat plate collectors and that solar energy can provide energy for the drying of grain. The economics of this system of grain drying, however, have not been fully determined [8].

FLOUR MILLING

In case of flour milling the energy requirement is mainly effected by variety of grain, methods of grain cleaning, the milling system itself, types of flour produced, the type of internal transportation (mechanical or pneumatic) in the mill, and the type of electric drive of machinery (the group or individual one). The more modern the mill is (pneumatic and group drive), the more energy is used for milling [2, 3, 4, 17].

The average energy demand by a pneumatic flour mill in Poland is about 49 Kwh/t and for a mill with mechanical transport about 45 Kwh/t [1]. While discussing the possibility of energy saving and better utilization of raw materials the following aspects of milling should be taken into consideration.

First of all there is a distinct diverence between energy demand for milling different kind of grains, eg: if energy requirement for milling wheat will be 100, for rye it is 115-120, for barley 120-130 and for oats 140-160, respectively. There is also a difference in milling various varieties of grain at a different moisture content. Table 3 shows the data.

The energy requirement for milling hard whea (Kolibri) is lower than for milling the soft one (Grana), in particular with higher moisture

Table 3. Energy requirement for grinding wheat of different moisture content

Variety of wheat	Moisture (%)	Energy requirement
		J/g
Grana (soft)	11.9	126
	12.9	153
	13.2	255
	14.4	341
	15.6	413
	17.1	431
Kolibri (hard)	11.2	137
	13.5	160
	15.9	155
	16.7	185
	17.7	230
	18.9	345

content of the grain. Milling these grains at the moisture content of 11-12%, requires only about 130 J/g. In case of higher moisture content eg 15-18% energy demand for milling is 350-450 J/g for soft wheat and 150-350 J/g for hard one. This could be a real saving as hard wheat is generally considered better for bread making.

As it was mentioned above there is a difference in energy demand for milling rye or wheat. More specific data are given in Table 4.

Table 4. Energy requirement for milling wheat and rye Kwh/t of flour [15]

Type of flour (%)		Mill with transport system	
		mechanical	pneumatic
Wheat flour	72 extr.	56-65	86-102
	78 extr.	52-60	80-93
	85 extr.	48-55	67-77
	95 extr.	21-24	30-34
Rye flour	63 extr.	55-60	71-78
	80	45-50	59-65
	87	42-45	55-59
	95	22-26	31-36

As it may be seen from Table 4 the lowet flour ectraction from both wheat and rye the higher the energy demand, with rye being less energy consuming due to less complicated milling system of rye. Thus present tendency for eating brown bread produced from fluor of higher extraction (> 85%) may be an energy saving element.

The technological progress in preparation of the grain and in milling it self aim at the reduction of energy demand. This is done by intensive "dry" cleaning of the grain and the reduction of the number of rolls in the milling system.

It should be mentioned here, however, that modernization of the flour mills by replacing the mechanical transport by the pneumatic one, increases energy demand by about 8-15 Kwh/t. This modernization, however, is done in order to eliminate fire hazzard and to improwe hygienic aspects of the process.

BREADMAKING

Bread — the last but not least cereal product to be discused here belongs to high energy consuming food products of cereal origin and with high bread consumption in some countries it has an important share in energy consumption by the food industry.

Here again, the more mechanized the bakery, the more energy it uses. This, however, does not mean that mechanization and progress should not take place.

As it was calculated by Lewicki and Adamczyk [9, 16] the energy consumption in different stages of bread production is distributed as follows (Table 5).

Table 5. Energy requirement in the bakery [9]

Processes or operations	Energy use in %
Internal transport	16.6-17.8
Dough mixing	10.4-15.7
Dough dividing etc., forming etc.	13.3-23.6
Bread baking	49.4-53.2

The above shown main operations can hardly be replaced or reduced although new technologies and new ingredients used in bread baking do reduce somewhat the energy demand for dough mixing and formentation.

In the chain of breadmaking, better construction of baking ovens may be the most intensive energy saving element as bread baking itself demands the largest share of energy in the process of bread making. This subject however will not be discussed in detales here as there are papers aod posters at this Symposium beaking with this problem in more detales [10].

As the last element of this presentation we would like to show data concerning the whole cycle of bread production [7], from grain production to the loaf of bread (Table 6).

If we look at this table we will see where the energy in this cycle goes and where, if any, it may be saved. It shows in detales how the

Table 6. Total energy requirement in % for production of 1 kg wheat bread [7]

Growing wheat	19.4	
fractors		5.3
fertilizers		11.0
drying		3.0
Milling	12.9	
direct power		7.4
other		2.1
packaging and transport		3.3
Bread baking	64.3	
direct fuel and power		30.2
other items		17.3
packaging		9.0
transport		7.8

energy is destributed in different stages of "bread" production. It has to be mentioned, however, that this data concern British agriculture and a "British" loaf (probably the Charleywood one) and therefore they may not necessarly correspond with bread in other countries — but are very informative anyway.

As it may be seen from the whole presentation cereal storage and processing are highly energy demanding operations but proper understanding of these stages of cereal processing and the raw material itself may lead to better utilization of raw material under limited energy supply and to energy saving itself.

CONCLUSION

1. Grain storage and processing is one of the highest energy consuming branch of food technology.
2. Proper design and construction of grain dryiers may be an effective sources of energy saving.
3. More intensive utilisation of solar energy for grain drying and conservation should receive more attention.
4. Proper selection of grain and milling technology may also save energy during grain milling.
5. Breadbaking requires highest demand of energy (65%) in the whole cycle of grain production. Due to high energy demand for baking process alone proper construction and modernisation of baking ovens may provide substantial energy saving.

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ENERGETYCZNE ASPEKTY PRZECHOWYWANIA I PRZETWARZANIA ZIARNA ZBÓŻ

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Streszczenie

Przedstawiono ważniejsze aspekty zużycia energii w procesie przechowalnictwa i przetwórstwa zbóż. W czasie przechowywania ziarna jednym z najważniejszych aspektów energetycznych jest zużycie energii w czasie jego suszenia; w procesie tym zużywa się — zależnie od typu i konstrukcji suszarki zbożowej — od 3,9 do 16,3 MJ/kg odparowanej wody. Analizując przyczyny tej zmienności autorzy zwracają uwagę na bardzo duże straty ciepła w czasie suszenia ziarna. Zaledwie 40% ciepła zużywane jest na właściwy proces suszenia, tj. na odparowanie wody. Stąd też szczególną uwagę należy zwracać na właściwą konstrukcję i budowę suszarek zbożowych.

Zwrócono również uwagę na większą niż dotychczas możliwość wykorzystania energii słonecznej do suszenia ziarna zbóż (nawet w warunkach klimatu umiarkowanego).

Zużycie energii w procesie przemiału ziarna jest uzależnione od gatunku i odmiany zbóż, zawartości wody w ziarnie, stopnia wyciągu mąki oraz stopnia i typu mechanizacji młyna. Najbardziej energochłonne są młyny o pneumatycznym transporcie wewnętrznym, który jest coraz powszechniej używany (ze względów konstrukcyjnych i higienicznych). W porównaniu z transportem mechanicznym zużycie energii jest tu większe o 8 do 13 kWh/t mąki.

W procesie technologicznym przygotowywania chleba największe zapotrzebowanie na energię jest w procesie samego wypieku, w którym zużywa się ok. 50% całej energii. Pozostała energia jest zużywana stosunkowo równomiernie w czasie transportu wewnętrznego, miesienia i dzielenia ciasta.

Na zakończenie artykułu autorzy analizują cały proces produkcji chleba, od uprawy ziarna aż do wypieku i podkreślają, że najwięcej energii (65%) zużywa się w procesie przygotowania chleba. Pozostałą część energii pochłania produkcja i przemiał ziarna (odpowiednio 20 i 15%).