Int. Agrophysics, 1999, 13, 411-415

SIGNIFICANCE OF THE INVESTIGATION OF PHYSICAL PROPERTIES OF PLANT RAW MATERIAL FOR FOOD INDUSTRY

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A b s t r a c t. Investigations of physical properities of agricultural materials have been carried out in the Institute of Agrophysics of the Polish Academy of Sciences for many years. The investigations allow to deepen the knowledge of physical properties and processes concerning agricultural materials. They focus on mechanical, rheological, optical and thermal properties as well as their changeability during maturing, harvest and post- harvest processing. The studies have been curried out on the following material: grains, seeds, root of plants, fruits, vegetables, stems, pods etc. The general aim of these investigations is creation of better quality of final products (food). The quality improvement is mainly concerned with limitation of the degree of damage during harvesting, storage or other operations. The investigations allow also to indicate reasons and sources of damage of plant material. In consequence they resulted in elimination of operations and/or machines the most negatively influenced raw material.

K e y w o r d s: agrophysics, mechanics, rheology, optics, food, quality

INTRODUCTION

Production of plants is the main source of food in numerous countries of the world. Statistical yearbooks classify individual countries according to their production of cereals, protein plants, oil plants, fruits and vegetables. Export of agricultural products may bring considerable profit and indicates the level of the exporter's wealth. Quite recently, especially in the countries of Central and Eastern Europe, it was the quantity of the agricultural produce that was the most important. No attention was paid to the product's quality. Because of the political and economic conditions, the shortage of food products made quality disregarded. What counted, was satisfying basic nutritious needs of people.

Fortunately, in spite of these tendencies, for over 25 years in many Polish laboratories scholars were working out new methods and conducting research to estimate quality of plant raw material. In this way, they prepared a scientific basis for gradual popularisation of their methods.

There is no doubt that the food chemistry is one of the most important branches of science. It deals with the analysis of food products and identification of antinutritious components that are harmful for our health. Such undesirable components frequently appeared in plant materials of low quality which were obtained, stored and processed in a wrong way. Chemical changes in products are often caused by physical reasons. For instance, if harvested grain is damaged mechanically, invasion of various microorganisms, fungi, and mould will very soon lead to deterioration of the product's quality or even to its disqualification. In such cases losses are hard to estimate.

It is obvious, that in the case of potatoes, which are damaged during harvest and stored in wrong conditions, losses both in quantity and quality may be as high as 50% of the crop. A similar situation may often appear with fruit and vegetables, which are stored for several months.

Quality of all kinds of berries, which contain high percentage of water, decreases almost immediately during transport and storage, especially if they are overripe or a variety is liable to damage. Many similar examples may be quoted here.

ROLE OF AGROPHYSICAL INVESTIGATIONS

Prevention of such phenomena is closely connected with the recognition of physical properties of agricultural material [3]. First of all, we should be aware of the range of changeability of the physical properties that depend on the species, variety, moisture content, ripeness and other factors, which narrow or widen this range, for example soil, weather, agrotechnology, fertilisers and plant protection. Research on the physical properties of plant raw material requires appropriate standard equipment, even though prototype appliances are still used in many centres. Here, we encounter serious methodological problems, because final results are not comparable even for the same objects of research. Therefore, we can observe lack of co-ordination and co-operation in research, and certain methodological norms, which should standardise the measurements. So far, no scientific institution has made an attempt to suggest the necessary standards which would be accepted by the whole body of agrophysical scientists [1,2,15,18].

It is worth mentioning that in Poland we have certain assessment standards for the geometrical features of grains, bulk density of grain, mass of 1000 grains and some features of cereals and oil plants, which are connected with processing technology. Therefore, we can describe basic physical properties, but many other standards still have to be established. This task seems to be a challenge and an inspiration in this field in the nearest future for all the scientiest involved in agrophysical research.

In our opinion physical properties of plant material may be divided into several groups, namely:

- *Geometrical features* - must be known for the construction of harvest machines and for food processing and storage.
- *Mechanical properties* - define the material's susceptibility to damage and the influence of various external factors during harvest, transport, storage and processing.
- *Optical properties* - describe colour changes, which depend on genetic features, ripeness, changes of chemical contents, enzyme activity, diseases etc.
- *Diffuse properties* - characterise gas exchange that is especially important during the process of drying and storing.
- *Electric properties* - should be known especially during the procedure of cleaning and sorting of some grains, and also during the process of their stimulation.
- *Thermal properties* - are mainly connected with drying, cooling and freezing of the agricultural material.
- *Aerodynamic properties* - are significant during grain separation, which takes place at the harvest, during the process of cleaning and internal transportation.

Apart from these, there are also some other qualities, which characterise material and knowledge that may be helpful for certain operations and technologies. These are for instance: density, roughness of the surface, the angle of repose, and finally the porosity of the mass.

ROLE OF THE INSTITUTE OF AGROPHYSICS (EXAMPLES)

In the Lublin research centre all the above mentioned properties are examined in scientific co-operation between the Institute of Agrophysics of the Polish Academy of Sciences and local universities. The agrophysical research includes all kinds of subjects that may be helpful in finding the most suitable parameters of materials for food industry. First of all, it is vital to find the range of variation of the physical properties of materials in relation to various factors both internal and external. Next, it is important to trace the reasons and causes for unfavourable phenomena (such as damage). The next step is to describe these processes and find such

solutions, which will eliminate undesirable and negative effects, and will guarantee high quality of the plant material for food industry.

In our environment we may already find some instances of similar procedures, which have brought measurable profits in practice, for example co-operation and the exchange of scientific information with the University of Agriculture in Lublin.

Lublin region produces almost 90% of hop in Poland. Harvest machines that were used for gathering hop cones used to bring about significant losses both in quantity (many cones were left on the plants) and in quality (numerous cones were crumbled).

Investigation on the force with which the cone was connected to the plant showed that this force can be very varied, and this fact produced very negative results in practice. On the basis of our research, Lublin breeders managed to grow a special variety of hop with cones were loosely connected to the mother plant. This variety of the hop has become extremely popular nowadays. It produces plant material of the highest quality at harvesting. It brings expected profits to the breeders. Co-operation with the Lublin breeders showed an interesting regularity. It turned out that physical properties of plant material are inherited in much greater extent than any other features. Seeds selected for the crosses were characterised by high resistance to mechanical damage. The grains bred from the new forms turned out to be extremely resistant to any mechanical factors. At the same time, the material produced retained favourable chemical properties which satisfied requirements of the quality standard. The fact that plants inherit physical features to such a great extent opened new paths for controlling and shaping the breeds so that they posses the most favourable properties.

Another instance of a complex agrophysical research which brought unexpected profits, was a new technology of rapeseed harvesting. We investigated mechanical properties of pods and seeds from various varieties of rape. The studies took into account the influence of various factors. Finally we managed to establish the reasons for losses in quantity, and the causes of damage taking place during harvest and further processing of rape [11-17].

After analysing database, which was completed during a few years of research, we designed and carried out an exchangeable adaptor for the harvest machine. This adaptor was exclusive for rape. Alongside a whole range of regulations for the harvest machine subassemblies was designed. This regulation range was designed to suit a given rape variety seed moisture level. As a result, quantity losses were reduced to the minimum, and seed damage fell below the standard level.

Now, after elimination of the sources of seed damage in processing after harvest, food industry obtains plant material of the highest quality. The new technology has been employed in all the regions of Poland, where total number of rape fields amounts to about 500 000 ha.

In the Institute of Agrophysics in Lublin we conduct a large-scale research on basic physical properties of plant material. One may hope that the results achieved will improve the materials for food industry and will enable us to assess them objectively. A few more examples are given below.

The research carried out at present aims at elaborating the most favorable conditions of rapeseed storing for fat industry. It includes estimation of seed technological value with respect to oil content, chlorophyl content, acidity and peroxide number as well as microbiological evaluation and seed mechanical resistance.

Changes in seed quality can be obtained in strictly specified storage conditions in grain silos. Pressure chambers are used to simulate these conditions because of the fact that they allow to control temperature, moisture content, load on seeds and constant monitoring of changes that take place in the stored material.

Another investigation carried out in the Institute of Agrophysics on rapeseed are related to seed resistance to dynamic load. When exposed to dynamic loads, seeds were damaged - the size of damage depended on the following factors:

- seed moisture,
- rotary speed of the striking element which corresponded to the rotation velocity performed by the threshing drum in the combine harvester.

Consequently, decreasing seed moisture content and growing rotary speed were accompanied by increasing macro-damage. It has also been noticed that there was a rapid growth in micro-damage which could be observed in those seeds which had 20% of moisture at the minimum tangential velocity of 3 - 6 m s^{-1}. The results obtained show that rapeseeds are extremly susceptible to mechanical damage. Hence, any technological treatment of this crop should be carried out with special care in order to preserve its quality.

Another example of our activity is also related to damage, but this time of wheat grains [4,8,9]. In order to preserve the taste and dietary qualities of food products made from wheat, a producer needs flour made from high quality grain. Consequently, in Poland there is a growing interest in the variability of grain physical characteristics (resulting from quickly changing demand) and new ways of classification and qualitative evaluation of products. Major changes in the internal structure of wheat kernel - a consequence of mechanical and thermic factors (external forces and high gradients of moisture content before, while and after harvesting). The application of X-ray detection and computer analysis made it possible to figure out the place, size and nature of internal changes. Evaluation of the grain physical condition after its exposure to a number of factors (static and dynamic forces, moistening and drying) constitute the net result of the study. Cracked grain seems to absorb moisture faster. It is also more susceptible to infections with microorganisms, has lower mechanical resistance and can be easly broken into fragments when it undergoes various technological processes.

The last example is related to optical properties of plant material. Browning of apple tissue occurs upon bruising, during handling or transportation, also when exposed to air in the cutting, slicing or pulping processes. An important quality attribute of sliced tissue prepared commercially is its white colour. In the study, genetic and natural potential of apple varieties received particular attention because of their multiple effects on browning development [5-7,10]. Also the method using "redox potential" of tissue has a great value as a means to evaluate freshness and quality of minimally processed fruit.

CONCLUSIONS

All the above cases show the extent to which complex agrophysical research may improve quality of products used in food industry. It is a general conclusion which should be treated as a principle. It is obvious that physical properties of plant materials change under the influence of certain factors, which can be easily estimated. However, during various technological operations such as harvest, transport, drying, cleaning, storing and processing, there are a lot of tools and machines, which have to be used. Besides, temperature also changes during all these processes.

Thus, in order to obtain plant material of the highest quality it is essential to estimate mechanical properties of a given substance. It is also important to examine the effects of machines. This will help to eliminate or improve components which decrease quality of plant material. It is indispensable to control the material quality at every stage and to examine its technology because food produced later must satisfy quality requirements.

Physical properties of plant materials and food become a very wide subject if we take into account great variety of substances, different ways of processing and multitude of food products. However, it seems that the basic aim of research in this field is to obtain materials of the highest quality.

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