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MICRO-STRUCTURE AND QUALITY OF RAW MATERIALS AND FOOD PRODUCTS

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Abstract. Nowadays, the quality and safety of food are of crucial importance. Not only are the technological parameters of production decisive for the highest quality of food but the quality of the raw material being processed is of the utmost importance. On the one hand, the good quality of raw materials can easily be reduced, but to obtain top quality products from such material is hardly possible. Plant materials which are the subject of the paper have to pass a long way "from the field to the fork", before to be a ready to eat. They are very sensitive to some environmental and technological factors. Using the microscope methods LM, SEM & TEM, the structure of plant materials, the relation to physical properties as well as the changes taking place in processing which cause undesired changes in their quality, are shown and discussed.
Keywords: plant materials, microstructure, quality, processing, storage, diseases

INTRODUCTION

The properties and quality of all raw materials used in the food industry are of crucial importance to the safety and quality of food. It is well known that food processing can only improve the poor quality of the raw materials to some extent; it should be rather eliminated at the stock delivery stage, or at selection or when cleaning. Recognition of the weakest points in the food production chain is therefore necessary not only for food technologists but also for the farmers who grow, harvest, dry and supply the very many raw materials which are very sensitive to unfavourable biological, chemical and physical environmental conditions.

Despite traditional methodology in evaluating materials which is given in national or international standards, other, more sophisticated, tools are very often applied. Very interesting possibilities are available by using microscope methods. Optical microscopy (LM) with its large potential (bright field, fluorescence, UV, polarized light, Nomarsky, staining procedures and/or different wavelengths), electron microscopy (TEM and SEM), confocal laser microscopy (CSLM), X-ray microscopy or finally atomic force microscopy (AFM) are more and more often used not only to visualise some effects but also to detect some symptoms of the deterioration of material hidden from producers' or consumers' eyes [1,2,4,9,11, 14,15,19,21,24].

Microscope methods in the food production chain are applied, among others, in order to analyse the relationship between structure and:

- quality of raw material and its storability,
- technological parameters of processing,
- functional properties of final products,
- localisation of food components and their interaction with the products,
- changes in the food components during storage and processing, and
- some additives and product texture or quality.

In this paper, selected raw materials, processes and products are shown in order to visualise some of the above-mentioned relations important to raw materials and product quality.

CEREALS, LEGUMES, AND OIL SEEDS

This group, being the majority of crops produced all over the world, and the basic element of our daily diet was selected as the first example for visualisation, using microscope methods, of possible strong and weak points decisive for maintaining quality.

Cereal, legume and rapeseed grain geometry and seed-coat surface characteristics are the first structural elements that can be regarded as decisive for properties important in transportation, cleaning and storage (fig. 1a,b,c,d). Surface elements (fig. 1b) are of great importance to such physical properties as friction coefficients or bulk density. Surface roughness ranging from 0.5 to 10 μm for different grains or seeds can be regarded as an important factor for diversification not only between seeds of different species but also between varieties of the seeds with the same geometry and weight or colour, i.e. lentils of different varieties and chemical composition (fig. 1c,d) [8,11,18,23].

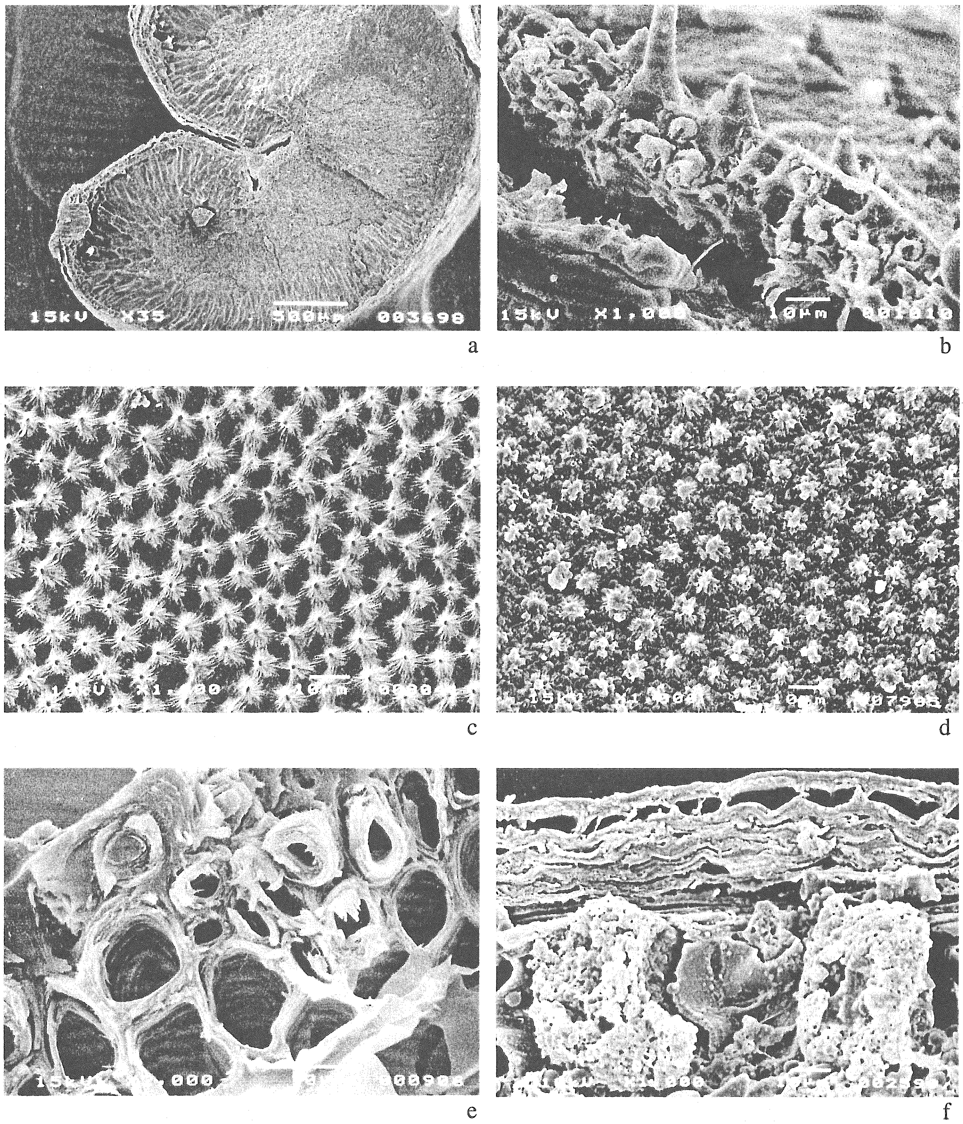

Fig. 1. Outer part of cereal kernels: a – cross section of wheat; b – surface aspherities of barley, c – and d – surface of different varieties of *Lathyrus sativus*, e – hull of barley, f – seed coat and aleurone layer of wheat

The seed coat protects a seed against external forces during harvesting and post harvest treatment as well as against diverse environmental pollutants (heavy metals, PAH, etc.) being absorbed first (fig. 1e, f).

In some cereals like barley (fig. 1e) and/or oat, the husk plays an important role in storage and processing. It is composed of such layers as the outer epidermis, hypoderm, parenchyma and inner epidermis, and protects the seed from water, mechanical forces as well as mould infection. A mould-infected grain surface is shown in figures 2a and 2b. The dominant elements of the pictures are mycelium and conidia with conidiophores. In processing, the composition and structure of the seed coat or husk are decisive for such operations as steeping and conditioning prior to removal of the hull. The strength of the binding with the seed coat is decisive in turn for energy consumption during husk or seed coat removal as well as for efficiency in processing. The aleurone layer, next to the seed coat (fig. 1f), containing many biologically active compounds, important from the nutritional point of view, is very often removed to the bran fraction during milling.

The internal structure also influences the mechanical properties of grains. Despite external forces acting on grain during post harvest treatment where mechanical resistance is required, figures 2c and 2d illustrate the endosperm of wheat kernels of different rheological properties influencing also milling and the end use properties of the material. It is evident that wheat kernels with a mealy structure are composed mainly of large and small granules only slightly connected with adhering protein. The proportion between the number of small and large granules is around 3:7. For this reason such wheat grains are destined for flour production. During milling, the endosperm cell fragments are divided into very small fragments and low energy for such process is required. Horny or vitreous endosperm is typical of hard wheat from which coarse fractions are obtained. In the case of durum, the semolina fraction is the basic material for pasta production.

One of the storage chain elements is very often the drying process. Temperature action on moist tissue of seeds, when optimal conditions are not always kept, result mainly in such deep changes in the structure of the seed that it becomes useless for any further process and should be eliminated from the stock. The potential extent of the structural changes is shown in figures 2e and 2f where microwaves have been used as a source of energy for drying wheat grain. The break up of the continuity of grain tissue as well as the denaturation of proteins that create their unusual fibrillar structure are the most dominant phenomena observed [3,17].

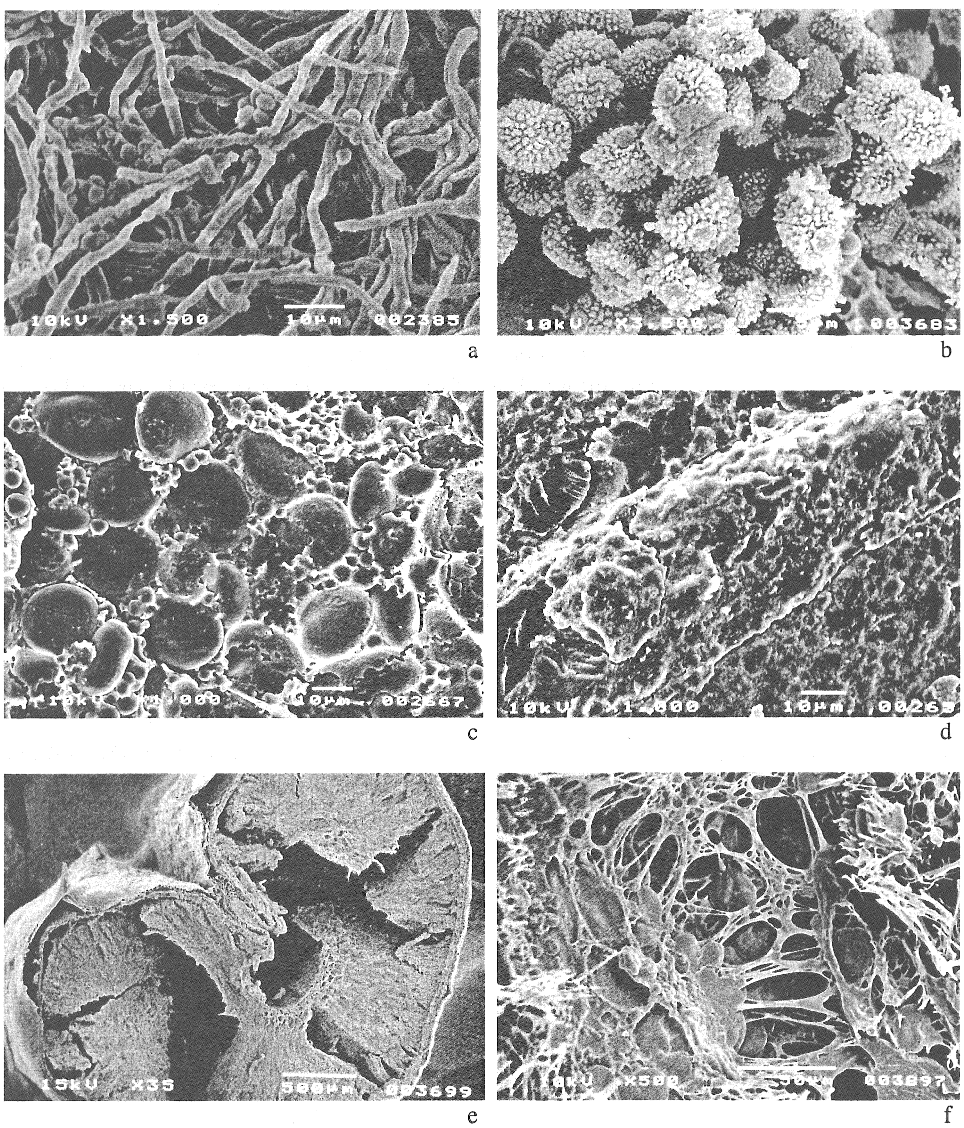

Fig. 2. Microstructure of what kernels: a and b – infected by fungi (mycelium and spores, respectively), c and d – soft (floury) and hard (glassy) endosperm cells of different wheat varieties, e and f – microwave action on moist grain

Even in the dry state, grains or seeds are often attacked during storage in bins or elevators by some insects causing losses not only to their technological value but also high economical losses. One such insect is the granary weevil (*Sitophilus granarius)* infesting mostly wheat grain. Its activity, dust production and time of development are also dependent on the mechanical properties of grain - mainly hardness. It is very important to find a method to detect any such infestation very early even at the egg laying stage. Such possibilities are offered by X-ray methodology, which enables differentiation of the subsequent stages of insect development (fig 3a and 3b).

In legume seeds, the seed coat with its external cuticle being the first barrier for water penetration into cotyledons is also non permeable to many polar and non-polar solvents (fig. 3c and 3d). The palisade layer, the hour-glass cells and the spongy parenchyma together with the hilum, hilar fissure and the microphyle or raphe are responsible for the sorption-desorption processes important in soaking (conditioning) or drying. Water sorption during the first three hours is dependent on seed hull structure, the subsequent adsorptive properties and the opening of the hilar fissure and then finally seed hydrocolloids [10,13,23].

This particular part of the seed can create some problems in the post-harvest treatment, e.g. drying prior to long-term storage. The impermeability of the seed hull in legume seeds during drying in moderate or even low temperatures is an important factor affecting the percentage of seed damage. When seeds are dried at such low temperatures as 40°C, external and internal damage appears (fig. 3e and 3f). It is clearly visible that the raphe (due to the action of embrional axis working as a wedge bursting the cotyledons) seems to be the weakest point of the seed. Inside the cotyledons, internal cracks have a tree-like shape with the main line also starting from the embrional axis. The changes found were decisive for drying technology modification with a necessary break for water equilibrium in the bulk seed or other grains admixture, easily separated after drying due to different geometrical parameters [5].

The negative influence of post harvest drying on the technological properties of rapeseed is shown in the TEM pictures (fig. 4a and 4b). Drying under extreme conditions which sometimes happens during rainy harvest weather and occasionally using dryers not destined for such delicate seed as rapeseed, reduces quality vis à vis further processing [6,7,22,25]. The extractability of the crushed press-cake with hexane is very limited or almost nil, resulting in the high oil content of the meal. The reasons for such a drastic lowering of technological value were the denaturation changes of protein bodies, damage of the lipoprotein membranes surrounding the individual oil droplets and the gathering of free fat near the cell walls, thus provoking very high adhesion and cohesion forces making penetration of the solvent impossible.

Some legume seeds are characterised by properties called the 'Hard to Cook Defect' (HTD), which means the prolonged time required to boil to the desired texture. This is connected with the above-discussed seed hull structure and composition (seeds fail to soak up water – Hard Shell) from one side and from the other with the chemical side of the cotyledon [13,23].

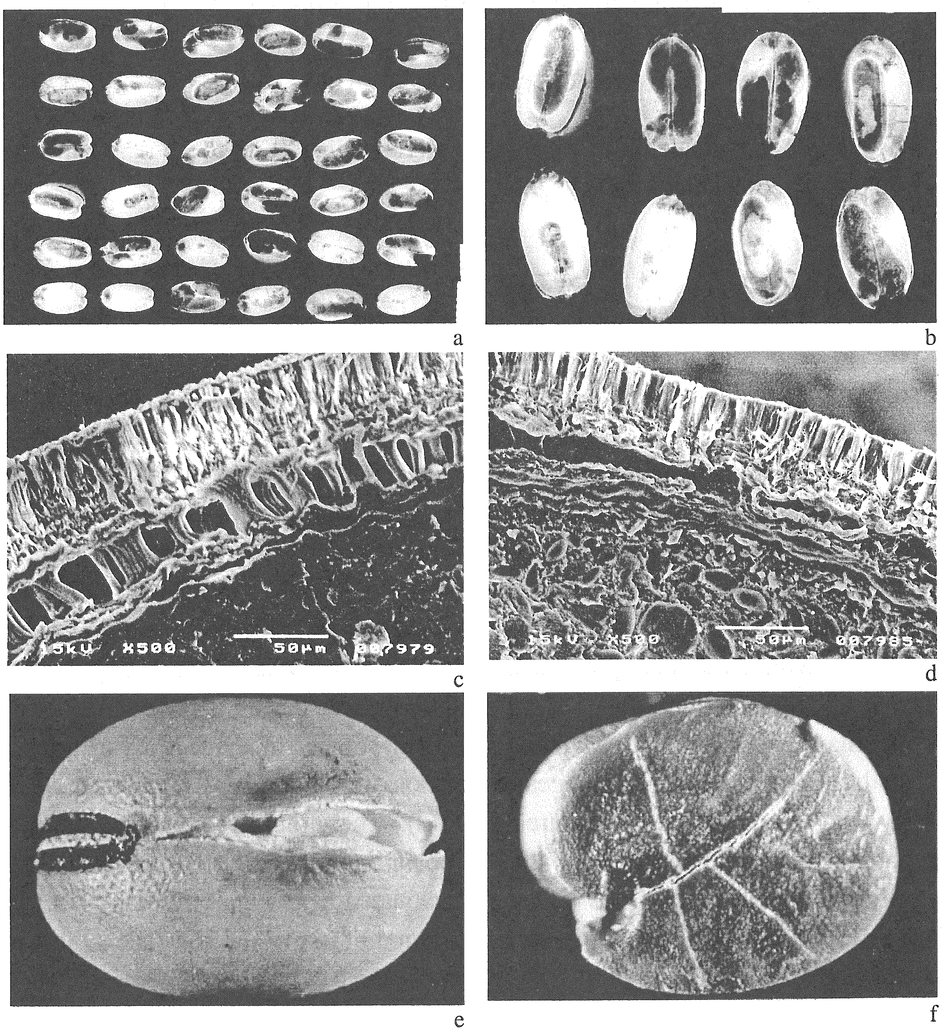

Fig. 3. Possible grain/seed damages: a and b – wheat grain infected by *Sitophilus granarius*, c and d – seed coat of *Vicia faba* seeds of different mechanical strength and permeability, e and f – damages to legume seeds during drying (outer and inner, respectively)

Pulsed field MRI, a new tool for the scientist provides information on the differences in diffusion coefficients. At high differences in bean hardness between control and hard seeds (0.33 N vs 6.53 N), diffusion coefficients are also different: 0.76 and 1.53 or 1.73 and 1.03 x 10^{-10} m^2 s^{-1} after 2.5 and 48 h of soaking. These differences are connected with the rapid collection of water in spaces between the cotyledons and the seed coat and the cotyledons' inner surface but water uptake by the cotyledon cells is inhibited more in hard than in soft seeds [1,24].

FRUIT AND VEGETABLES

The apple was selected as a representative for fruit and the potato tuber was selected as a representative for vegetables.

Apples

In the case of the apple, cellular structure is responsible for the texture expressed as hardness, bite or juiciness. The structure of an apple can undergo changes during transportation (bruising) or storage (sandy texture development), as well as during processing (juice production). Bruising is the term describing the result of the action of external forces on the plant's tissue resulting in changes, mainly physical, in texture and chemical, in colour and flavour [16,20]. Apple skin with its waxy cuticle, epidermis and hypodermis is responsible for sorption-desorption processes (fig. 4c). Apple flesh consists of cells and intercellular spaces, the size and number of which are regarded as factors influencing textural quality associated with fresh and processed fruits and vegetables. The changes in the volume of cells and the number of intracellular spaces during apple storage as well as the changes in the middle lamella consisting of pectin that are hydrolysed by polygalacturonase, result in changes in organoleptic properties - mainly on apples' crispy and juicy or sandy texture (fig. 4d). These are usually very complex preparations composed on the basis of pectinesterases which transform highly esterified apple pectin particles to lower methylated or polygalacturonic acid. As a final result of changes in apple tissue, a separation of individual cells takes place and when consumed, intracellular juice is kept inside the cell walls which gives a 'sandy' texture. In contrast, in fresh and correctly stored fruits the cell walls tightly adhere to each other when chewed and then crack open resulting in a leakage of juice.

Potatoes

Potatoes are an important dietary component in some countries. The potato tuber is a metamorphosed swollen stem. On the cross section, different zones of the tuber are clearly visible. The first – the skin – is composed of protective tissue, protecting the tuber against mechanical as well as other damage. Next to the skin is the vascular ring (conducting tissue). Between both these there is the cortex. In the centre is the translucent pith. This particular part is very low in dry matter. The most important part of potato tuber is the perimedullary zone located between the vascular ring and the pith with the parenchyma cells containing the starch granules, characterised by their clean, smooth surface. Starch granules being present in the dry mass of tubers (up to 75%) are the main component affecting the texture and quality of the cooked, fried, mashed or canned potato [12].

Due to the high water content and the delicate structure of potato tubers, they are prone to mechanical damage very easily. Mechanical harvesting and transport as well as some unfavourable storage conditions are reasons for such tuber damage as brown and dark spots on the flesh – and 'black-spot' which is a form of bruising.

Mechanical damage is not the sole challenge facing the potato industry. There are many viral and bacterial diseases as well tuber pests that cause deterioration of the tuber quality.

More often crop losses in Polish potato production result from pathogen-infected seed; these are one of the main reasons for low yields across the country. The potato can be infected by over 90 potato pathogens [12]. These micro-biological diseases can be identified entirely by internal and external tuber symptoms. The quality and localization of symptoms on the tuber surface is often important in diagnosing such diseases as common scab (*Streptomyces scabies)* or black scurf *(Rhizoctonia solani)* (photos not presented). However, diagnosis of such pathogens as *Fusarium* or *Alternaria solani,* which cause disorders in the deeper part of the potato tissue, is very difficult (photos not presented).

For the majority of viral, fungal and bacterial diseases, however, an examination of both the external and internal tuber symptoms is required for any proper diagnosis.

Besides the above-mentioned pathogens, potato viruses are among the most important disease agents. In Poland, PVY, PLRV and PVM are viruses of economical importance. Up to 50% of qualified seed production is declassified due to viral infection, mainly with PVY in the group of susceptible cultivars (unpublished data).

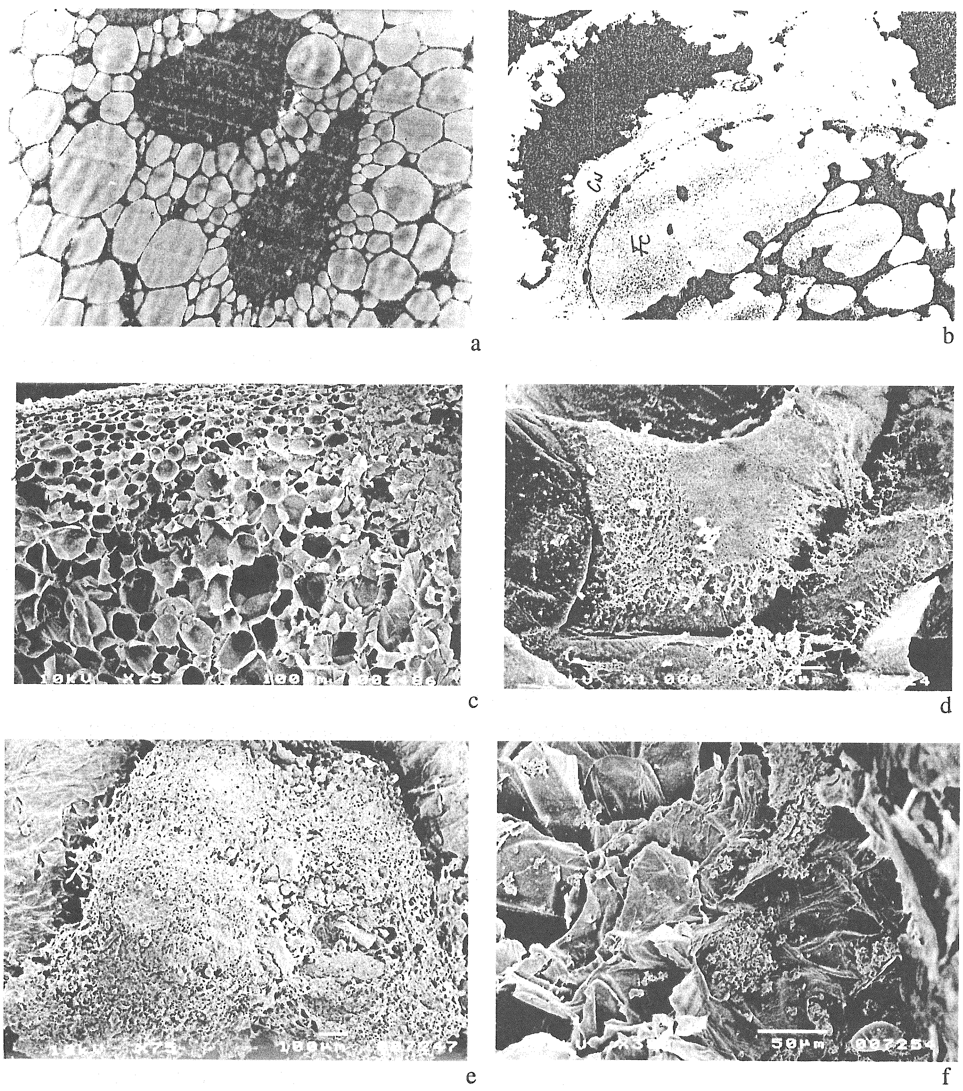

Fig. 4. Rapeseed, apple and potato microstructure: a and b – raw and over dried rapeseed (TEM) c and d – apple flesh of juicy and sandy texture, e and f – potato tissue infected by PVYN virus

The PVY^N causes some damage not only on the surface of the tuber (the widely spread brownish necrotic areas) but also in the deeper part of the phloem tissue (figs. 4e and 4f). The pictures presented clearly show a concentration of strand-like structures in the outer part of the cortex as well as in the perimedullary zone.

CONCLUSION

Only a few examples have been given on how some weak points in plant crop treatment can influence the structure of material – which is in turn of great importance to the quality of a processed product. We hope that this paper will encourage not only agrophysicists but also food technologists to visualize the results obtained, by routinely using the methods discussed in the microscopic methodology. In our opinion, microscopy is one of the best tools for the precise and complete characterisation of materials and products of different origin with respect to their quality and safety.

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MIKROSTRUKTURA A JAKOŚĆ SUROWCÓW I PRODUKTÓW ROŚLINNYCH

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Streszczenie. W dzisiejszych czasach jakość i bezpieczeństwo żywności wydaje się być szczególnie istotne. O wysokiej jakości żywności decydują nie tylko parametry technologiczne produkcji ale przede wszystkim jakość przetwarzanego surowca. Dobrą jakość surowca można łatwo pogorszyć w procesie technologicznym, a otrzymanie z gorszego surowca produktu o wysokiej jakości jest mało prawdopodobne. Surowce roślinne, które stanowią temat niniejszej pracy, muszą przejść długą drogę „od pola do stołu" aby stać się produktem gotowym. Są one zatem narażone na działanie wielu czynników środowiskowych i technologicznych. W pracy pokazano przy pomocy metod mikroskopowych (mikroskopia optyczna, skaningowa i transmisyjna mikroskopia elektronowa) i omówiono strukturę surowców, jej wpływ na fizyczne właściwości a także zmiany w procesie przetwórstwa, co może być niekiedy bezpośrednią przyczyną znacznego pogorszenia jakości produktu.

Słowa kluczowe: surowce roślinne, mikrostruktura, jakość, przetwarzanie, przechowywanie, porażenie