Int. Agrophysics, 1998, 12, 43-47

IMPACTS OF TECHNOLOGIES ON PHYSICAL PROPERTIES OF AGRONOMIC MATERIALS

H.J. Hellebrand

Institute of Agricultural Engineering Bornim (ATB), Potsdam, Germany, E-mail: jhelle@atb.uni-potsdam.de

A b s t r a c t. Different ways in which agricultural and other technologies can impact the physical properties of agronomic materials are discussed. Direct and indirect effects of these technologes are shown. The necessity of further research especially on the genetic engineering is proposed.

K e y w o r d s: agronomic materials, technologies, physical properties

INTERACTION OF TECHNOLOGIES AND PROPERTIES

A certain technology is always designed as a sum of procedures for transforming materials into materials with new or changed properties. Usually the input materials are called raw materials and the output gives products, which might be the input for the next technology or the products are consumed. All technologies are based upon three categories: materials, energy and information. Due to the applications of technologies the entropy of the whole system increases, but technologies might be considered to be entropy separators. This means that there are subsystems, where the entropy will be reduced by the work performed and in parallel entropy is increased in other subsystems (including export of entropy). The change in entropy is the physical background that we can define directions of flowing and changing, as indicated by arrows in Fig. 1. Entropy as a thermodynamically function of state does not belong to physical properties, but it can be utilised for the evaluation of environment related aspects of technologies. Environmentally friendly technologies will contribute to the total increase of entropy on a small scale only. If it is possible to evaluate technologies numerically in terms of variation in entropy, then the optimum will be get by minimising the total increase [12,13].

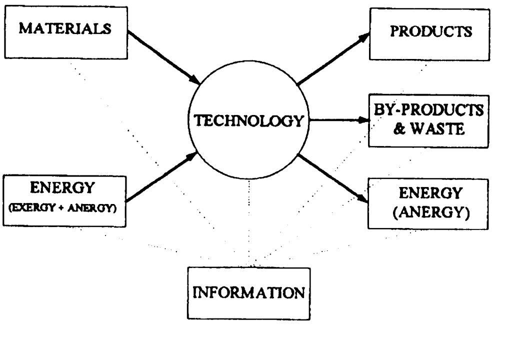


Fig. 1. Scheme of the categories from material to products.

Since technologies are developed to modify some selected properties of the materials in a definite way, there is an impact of technologies on the properties of the material processed. On

Table 1. Survey of few relevant technologies, properties, and materials. Marked lines indicate as example the impacts of drying on properties of grains

Type of technology		Physical property: Basic	Physical property: Composed	Agronomic material
Agriculture and Horticulture	Soil cultivation	Mass		Soil
	Planting	Volume		
	Sowing	Density		
	Fertilising	Shape		
	Weed treatment	Surface		Roots
	Spraying	Viscoelasticity		Fruits
	Harvesting	Stiffness		Grains
	Drying	Strength		Plants
	Cleaning	...		...
	Sorting	Colour		
	Storage	Colour distribution		
	...	Spectral absorption		Manure
		Dielectricity		Fertilizer
Animal keeping	Milking	Permeability		...
	Feeding	...		
	...	Heat capacity		
	Breeding	Moisture		Biocides
		Sorption		...
Science and Engineering	Aeration	...		
	Heating		Ripeness	
	Air conditioning		Smell	
	Controlling		Flavour	
	Physical engineering		Turgor	
	Chemical engineering		Composition...	
	Genetic engineering			
	...			

the other hand, technologies must be designed in an appropriate way to handle the materials concerned. For this reason we have to speak of interaction between technologies and properties of materials. To go deeper into the details one must specify technologies, materials and properties. When considering technologies and properties we find a tremendous number of possible combinations (Table 1).

Physical and other effects are used for designing of technologies. The properties of the materials, its dependencies and variables, and its relation to the structure of the material should be known in order to influence the change of the material as desired. Such a way the impacts of technologies on the materials processed and products gained might be controlled.

IMPACT OF DRYING ON MECHANICAL PROPERTIES OF GRAINS

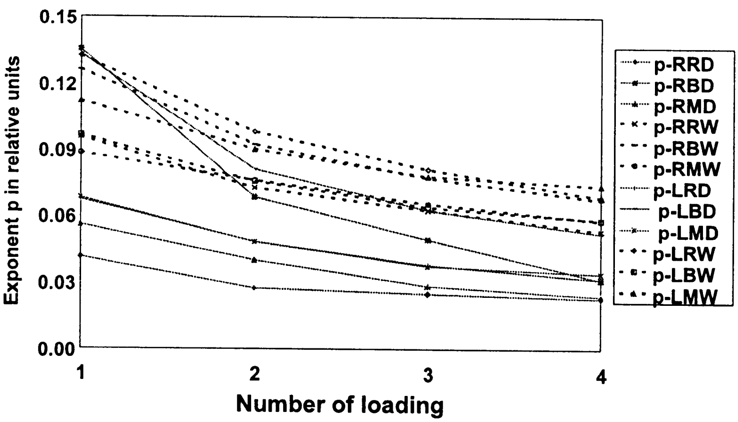
It is a well-known effect that the water content of plant materials determines the mechanical properties of the material. The turgor pressure of cells is one of the reasons. Tissue strength changes with turgor. The turgor pressure is controlled by cell walls and osmotic water transport in connection with ion concentration inside and outside of cell walls. The water molecules inside the cells are free movable (free water). The mechanical properties of plant tissues depend on the mobility and net structure of long chain molecules. Water is adsorbed at surfaces of fibre molecules (bound water). This water stabilises the spatial structure of molecules by hydrogen bonds. If this water is removed, the fibre structure will change. Two effects are possible in principle. When water is removed then crystalline parts may grow resulting in an increase of stiffness. This loss of mobility of the molecules against each other is observed in so-called frame or stroma molecules like cellulose and sclero-proteins. The other extreme is a complete change in spatial structure of the molecules leading to increased mobility of chain molecules like lipids (loss in stability of cell structures). The uptake of water molecules by wetting of dried tissues does not result in restructuring of the original molecules. Ones the structure is lost it can not be regained. Therefore the study of mechanical properties of dried and re-wetted substances will give different results compared with non dried products, although the moisture content might be identical. Measurements by Proton-NMR [9] a) and EPR-marker technique [9] b) indicate different water bond distributions for natural products and dried/re-wetted samples.

As a consequence for designing the drying process, in which mechanical properties should be controlled, the water content of the material must drop continuously without zones or intervals with moisture uptake by the material.

The effect of moisture uptake on mechanical properties of rice and corn kernels (fissuring) has been reported in several papers (*e.g.*, [7,11]). The evaluation of relaxation curves by several models [4] serves as an example for changing of mechanical properties due to drying and wetting. To demonstrate these changes, few results of the curve fitting by the model:

$$F(t) = Fo/(1+t/Tp)^p \quad (1)$$

shall be discussed. The difference between wetted and dried samples is clearly visible by repeated loading (Fig. 2). There is a correlation of the relaxation parameters to the moisture state (Table 2, Fig. 3).



with the abbreviations:
First symbol: type of model (p: Power Function)
Second symbol: type of sample (R- rice Ricco, L- rice Lemont, C- Corn, P- Popcorn)
Third symbol: processing (R- rough, B- brown, M- milled)
Fourth symbol: moisture state (E- oven dried 5 h at 105°C, D- sun dried, W- saturation moisture after 72 h at 100% humidity, F- sun dried samples exposed for 1 h 100% humidity, G- oven dried samples exposed for 1 h 100 % humidity)

Fig. 2. Change of parameter p in dependence on number of loading and on water state of single rice kernels (mean values of 14 kernels).

Table 2. Parameters *Tp* and *p* in dependence on moisture state (mean of the evaluation of 1st loading using the model (1) with *Fo* initial load)

Water state	E	D	W	F	G
Parameter *Tp*					
Rough rice	0.32±.17	0.12±.08	1.76±.56	0.49±.16	1.00±.50
Brown rice	0.30±.02	0.18±.13	1.04±.44	0.90±.58	0.48±.19
Milled rice	0.34±.11	0.55±.29	0.64±.31	1.33±.53	1.44±.43
Corn	0.55±.32	0.65±.33	1.13±.13		
Parameter *p*					
Rough rice	0.053±.005	0.063±.010	0.107±.018	0.090±.027	0.118±.004
Brown rice	0.059±.009	0.102±.022	0.111±.014	0.142±.010	0.177±.046
Milled rice	0.028±.003	0.062±.005	0.109±.019	0.135±.007	0.137±.026
Corn	0.032±.002	0.038±.011	0.089±.043		

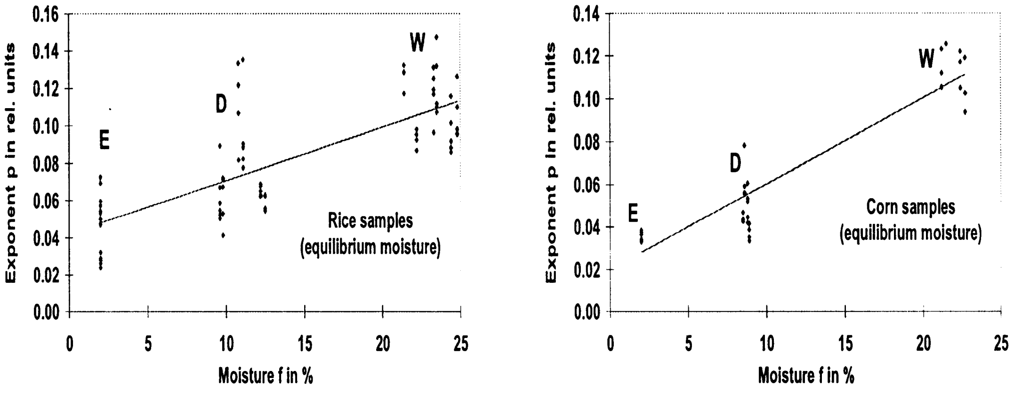


Fig. 3. Dependence of relaxation parameter p on moisture state (first loading; E - oven dried kernels, D - sun dried kernels, W - wetted kernels).

IMPACT OF FERTILISING ON COLOUR OF PLANTS AND PLANT PRODUCTS

The colour of plants depends on several factors. What we see is the reflected (remitted) light from the plant surface with a light active thickness of a few wave-lengths (about 2 .. 3 μm). The absorption is determined by the density of colour active molecules like chlorophyll or carotene in the surface cells. The availability of plant nutrients in the soil influences the development of these molecules. Although the chlorophyll density and activity depend on the supply with all necessary ingredients, usually nitrogen is the limiting factor in agriculture. If this is known, the colour evaluation of plants might be used for control of nitrogen fertilising (Fig. 4).

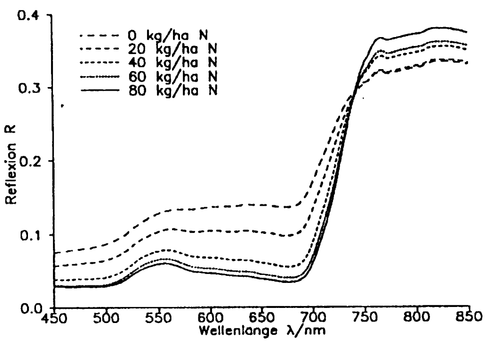


Fig. 4. Typical spectra of reflected sun light from rye with different levels of fertilising [10].

Different fertiliser level in the soil can affect the element concentrations in plants and plant products. In general, one differentiates structural and functional elements. Nitrogen, phosphorus and sulphur are considered as structural elements, since they are essential for proteins and other biomolecules. Chlorine and potassium are said to be pure functional elements. Other elements like magnesium and calcium can be found in both configurations. Only in case of functional elements a correlation between soil content and concentration in the plants should be observed [1].

There is an indirect way of influencing the uptake of elements. The fertiliser level of the structural elements N and P enables some plants to control the uptake of other elements like Ca, Fe, K, Mg, and Zn [5]. The content of metal ions is one factor for oxidation and changes in colour of cut products. The colour of fried products depends on several factors. Temperature and duration of frying are essential on the one side. On the other side the sugar content of potatoes and the content of amino acids are also responsible for the fry colour [2,3,6].

CONCLUSIONS

There are different ways, in which agricultural and other technologies can impact the physical properties of agronomic materials. In discussing this broad field it is possible to distinguish technologies by their aim and way of action. We find indirect effects such as influence of fertilisers on colour of plants and plant products. The actual knowledge on these indirect or unexpected effects is rather poor at present. There are direct effects when considering technologies as drying. Then the change in physical properties is expected and intended due to alteration of the composition and structure of the material. The connection between technological parameters and modification of properties is usually a function based on correlation. More research is necessary on the interaction of technology in conjunction the supplemental fields of structure and properties of agronomic materials. A third, now vary rapidly growing technology is genetic engineering. This technology is quite different from the examples mentioned here, since the acting principles of this direction are based on biomolecules. It acts selective as a rule. Usually genetic engineering is not utilised to alter physical properties, but this is not excluded, if properties as colour, mass, volume or shape are considered. This field of research will considerably affect the future agriculture.

REFERENCES

1. **Amberger A.:** Pflanzenernährung (Plant Nutrition). Eugen Ulmer Verlag, Stuttgart, 264 S., 1988.
2. **Briddon A., Cunnington A.C., Storey R.M.J., Jina A.:** Effect of Carbon Dioxide on Processing Quality. 13th Triennial Conference of the European Association for Potato Research, Veldhoven (NL), 415-416, 1996.
3. **Brierley E.R., Cobb A.H.:** The relationship between amino acid content and processing quality in stored tubers.13th Triennial Conference of the European Association for Potato Research, Veldhoven (NL), Abstracts, 611-612, 1996.
4. **Hellebrand H.J.:** Influence of moisture on the stress relaxation of single rice kernels and corn kernels. Proc. International Workshop 'Stress Relaxation in Solids of Biological Origin', ISASE, 70-77, 1996.
5. **Karadogan T., Akgul M.:** Effect of manure and fertilizers on the chemical composition of potato tubers and uptake of mineral elements. 13th Triennial Conference of the European Association for Potato Research, Veldhoven (NL), 210-211, 1996.
6. **Kari-Käri M., Kuisma P., Mustonnen L., Piettilä L., Tikanmäki E.:** Controlling Processing Quality of Potato. 13th Triennial Conference of the European Association for Potato Research, Veldhoven (NL), 417-418, 1996.
7. **Kunze O.R., Prasad S.:** Grain fissuring potentials in harvesting and drying of rice. Trans. ASAE, 21, 361-366, 1978.
8. **Kutscher J., Pfeifer H., Hunger M., Hellebrand J.:** Untersuchungen des sorbierten Wassers in Weizenkaryopsen mittels Protonenimpulskernresonanz (Study of Sorbed Water in Wheat Kernels by Proton Pulse Nuclear Magnetic Resonance). Experimentelle Technik der Physik, 34, 2, 113-122, 1986.
9. **Kutscher J., Hanke T., Ebert B., Hellebrand J.:** Application of ESR-spin probes - A method for investigating water in seeds. Int. Agrophysics, 117-126, 1986.
10. **Reusch S., Heege H.-J.:** Berührungslose Messung des Stickstoffbedarfs von Kulturpflanzen (Sensing of Nitrogen Demand of Crops). VDI Berichte 1211, 149-152, 1995.
11. **Shelef L., Mohsenin N.N.:** Effect of moisture content on mechanical properties of shelled corn. Cereal Chemistry 46, 242-253, 1969.
12. **Stahl A.:** Entropiegesetz und ökologische Krise (Low of Entropy and Ecological Crisis). Lecture held at the Meeting of the German Society of Physics, Berlin, 11 June 1992.
13. **Türck R.:** Das öklogische Produkt (The Ecological Product). Schriftenreihe Unternehmens führung, Verlag Wissenschaft und Praxis, 1, 254, 1990.