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EQUIPMENT SURFACES PREPARATION VS. FOOD STRUCTURE

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Abstract

Food structure belongs to the very complex and dissipative system. Mechanism of interaction and diffusion within that system, are determined by their chemical composition and also by physical structure of various constituents. This interaction is strongly affecting food engineering surfaces equipment. Their preparation regarding hygiene, quality, and safety food production vs. food structure changes during processing have been presented.

It has been stated that raw material, semi food product, and final products, creating the structure can be characterised by different responses against any surroundings either closed or open to the material mass flow. It has been noticed that the variable value of that reaction seen as the resistance forces to any contact visible or invisible surfaces, depends on the ways of possible interaction with that surfaces, and are related to the adhesive forces appearing during that contact. It can be said that between the food matrix structure, and surfaces to be in touch with them, there is a game played with different final effects. That game between both sides is continuously on the way "from farm to fork". On that ways there are many types of equipment surfaces being in touch with those materials. The final results of that game is creating the problems to cope with the removal of the remaining different soil on those surfaces, and to use adequate cleaning procedure to minimised food contamination. The effectiveness of that surfaces equipment preparation depends on the kind of soil and its adhesive value forces attachments.

Preliminary results of the final value, of food structure formation and resulting adhesives forces indicate, that both depends on its space configuration and rheological behaviour, on contribution to viscosity, surface tension and stability influenced by many factors: interfaces processes, moisture content, biochemical, microbiological, enzymatic and water activities.

Key words: *Surface equipment, Food structure, Adhesive forces.*

1. Introduction

All food systems are composed of ingredients that are physically and chemically balanced to give finally a harmonized product. In this complex food molecules structure in low-water environments, the interfacial surface phenomena with all forces from the strength of intermolecular interaction play a very important role in food functionality. From the food engineering and mechanical point of view, that functionality can be described as the specific response of food structure components to applied forces encountered during the preparation, processing, storage and consumption of food (Kokini *et al.* [2]; Matuszek [4]). The foodstuffs material faces loads of various magnitudes which deform the primary structure components. As food has a very irregular space composed structure, some components will be highly stressed to rupture while others will dissipate energy only as they are deformed viscous-elastically. The forces affecting raw materials, semi food products and final products during all ways of food engineering operations may include various form of energy applied. The resulting forces of that acting energy usually exposed their effects at any level in the hierarchy of food structure, i.e., from the molecular level to the formation of phases, networks, aggregates, cells, and finally to the food products themselves [3, 5].

There is also other effect of that acting energy. The results of that effects appearing at the many food equipment surfaces as the deposited there variety of soil. That involve the hygienic and sanitation problem to cope with adequate equipment surface preparation based on the final results of the contact phenomena between the considered engineering operation and the level of food matrix structure changes together with recognised type of soil and the value of attached it to the surface through adhesive forces [9].

1.1. A glimpse of theoretical research

The food physical systems mechanical behaviour can be characterised by two mechanisms - one, the deformability and compressibility of the solid matrix, and the other the build-up and dissipation of hydrostatic pressure in the deformed spatial arrangements of food components. This mechanical food systems behaviour can be seen as the results of the variations in collisions of particles and the relative translational energy of collision partners, and regarded as the energetic, kinetics and dynamics of molecule-surface interactions, adsorption processes, chemical reactions, and other physical processes which macromolecular collisions in the food system may open [7, 8].

The scale of the molecule-surface interaction will depends on the amount of energy absorbed. The range of food system deformation and its property changes based on contact phenomena at the process engineering, will be related to the resulting effects of the energy deformation that can be described by the following equation:

$$Edef = En + Ef + Es + Ev + Eb + Ed + Er$$

Where:

En - energy needed to break the network structure;

Ef - energy needed to produce a flow against the strictly viscous resistance;

Es - energy needed to produce a volumetric deformation;

Eb - energy needed to break the bonds formed by shear induced collision of particles;

Ed - dissipation or damping energy;

Er - radiation energy needed to produce the total or partial disintegration of the molecules (Matuszek [4]), based on the contact model in the food system, adapted and modified from Buczkowski and Kleiber [1], with permission.

From a technical point of view to select the individual component from the above equation and to present its domination in the food deformation process is a very difficult task because usually it is an imposition of a given strain within a very short time which is not easy to perform. For this reason, in case of viscous-elastic liquids, it is a typical in strength material experiment of alternative stress relaxation after deformation at constant strain rate (Fig.1).

The relaxed material is submitted to a constant rate of strain until steady flow is established. The rate of strain is then suddenly suppressed, and the decay of stress from σ_0 to 0 is recorded. In the linear region of the viscous-elastic behaviour, the stress relaxation modulus value can also be obtained. These curves are called the mechanical spectra of the material. Depending on the rheological characteristics of the food structure under investigation, one of them can give better insight to the behaviour than the other. Another typical feature in the food structure can be observed in the low frequency, i.e., during long observation time periods, that once again strongly depends on the rheological feature of the food structure components.

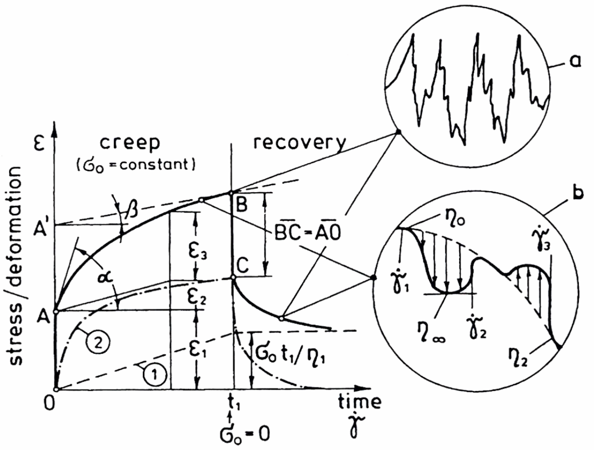

Figure 1. Viscoelastic flow and its recoverable contributions to the total deformation ε (*t*). γ, γ_1, γ_2, γ_3 are different values of share rate; σ_0 is stress: t_1 is time when the stress σ_0 is removed; η_1 is Newtonian viscosity; η^0, η_∞, η_2 are different values of viscosity.
(a) A picture of microfracture forces shown at the macrometer scale (b) The occurrence of shear thinning and thickening processes, inducing superstructures with reduced or increased values of viscosity

Figure 1(a) shows the micro-fracture forces as real amplitude changes of stress and compliance at the micrometer scale. Figure 1(b) presents schematically the occurrence of strong shear thinning and shear thickening processes. They can be expected in the flow of substances with structural viscosity for high molecular solution, and in the dilatancy, thixotropy, antithixotropy, and rheopexy flow. During these flows, the formation of shear induced superstructures with reduced or increased viscosity that can be observed at the nanometer or atomic size scales. It is compared to the system without long-range order, i.e., when changes between stress and compliance are presented as average values (dashed line).

The curves shown in Figure 1(b) display two plateau areas, which can be seen as low- or high-frequency regions. The first region can be interpreted as the concentration of dissipative processes relative to the flow involving large-scale changes in the relative position of the structural elements. The second can be interpreted as the dissipative processes relative to the softening transition, which involves local movements of the structural elements or their segments only. These changes in viscosity of investigated food structure systems, and related displacements of components structure, are not visible during classical tests. It could have been observed if different values of the parameters of the rheological model would have been taken (Matuszek [6]).

2. Materials and Methods

The purpose of experiment was to investigate the rheological and adhesives phenomena existing in the contact area between chosen examples of material used for manufacturing food processing equipment, and the amount of energy needed to overcome the resistance closely to the contact surface and samples, measured as the adhesive force (Pa).

Experiment was performed on the mixed species of parsley, chives and other vegetables as well as of chosen dairy, meat and fish frozen products. Before placed between contact plates the samples were kept separately and under controlled environmental conditions (20.0 ± 1.0 ^{0}C) with relative humidity of 60%. After a number of pre-treatment, samples were cut into the small particles, divided into several groups, put between plates made of different materials and with different surface factors (Ra) and located at different level in the freeze drying chamber.

The freezing processes were carried out in the bath operating equipment. All samples were prepared like foodstuffs dried in the freeze drying process. On the other hand it means that the samples were solidly frozen below their eutectic point. The drying system was capable of evacuation to an absolute pressure of between 5 and 25 microns of Hg, and a source of heat input to the samples was controlled between -40 ^{0}C and +65 ^{0}C accordingly to the heat of sublimation. With respect to the moisture content within the samples, the sublimation process was divided into three period of time.

The range of drying time and relationship between temperature and pressure were used for all samples placed at different selves in the drying chamber before taking them out for adhesive forces measurement.

3. Results and Discussion

The samples temperature and selves - inside and closely to the contact area, during the freeze drying process were measured through several sensors, mainly thermocouples. The amount of moisture and its movement within the volume of samples were determined by indirect method regarding the temperature distribution between samples dimensions.

Changes in the vacuum pressure were recorded by vacuum gauges. After finished drying process samples were placed between two plates made of different materials (types of steels, plastics, glass, and wood). In Figure 2 there is schematically presented measurement set for the adhesive force assessment. The contact force relevant to the dimension of sample, load, contact time, and the beginning of movement of upper contact plate were recorded through the tensiometeric beam.

Adhesive force was measured under controlled environmental condition similar to the adequate period of freezing drying process.

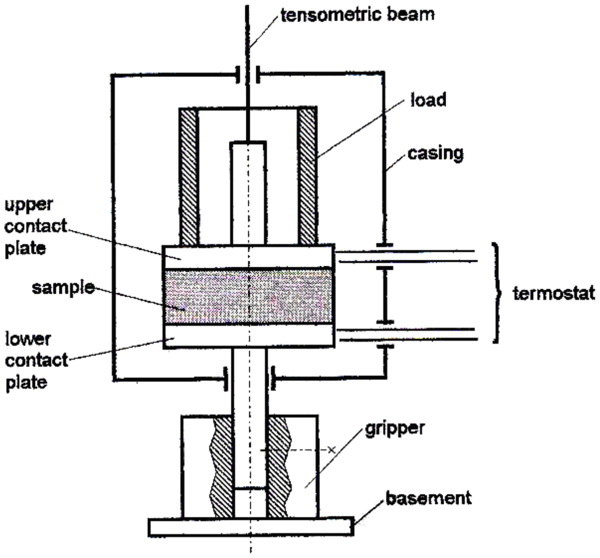

Figure 2. Measurement setup

The preliminary adhesive force (Pa) results shows that these forces contributes the surface resistance of samples and plates, and depend on duration time to be in contact. For example in case of parsley the value of maximum adhesive forces were in the range from 8.0 $N/m^2 \times 10^2$ for 15 seconds time in contact up to 18 $N/m^2 \times 10^2$ for 120 seconds time in contact. These forces within the contact zone characterising the internal friction of the several food matrix structure components together with their rheological feature in this food system network transformation process. It is expected that the not stable value of the adhesive forces could also be explained through other factors such as: molecular and cluster size, free volume and glass transition state changes in the food microstructure.

4. Conclusions

- It has been noticed that besides the different material plates, time duration contact, and temperature changes, there is a strong influence on relation between the surface geometrical characteristics mainly roughness, and the value of adhesive forces. From that there is also indirect information about the forces of soil remains and attached to equipment surfaces. Based on that, it is possible to calculate the adequate amount of energy needed in the food engineering equipment cleaning procedure to remove that soils and reducing contamination risk in the food production.

- Furthermore, it is also possible to assess the relationship between optimum energy against the value of surface roughness needed regarding the hygienic criteria, and cost of its preparation for minimising hazard during safety food production.

- Moreover, this optimum between energy and roughness can be further extended to include additional function, i.e., together with the model of microbial grows in the specific process engineering conditions.

- Finally, it can be stated that preliminary results of the food structure formation and resulting adhesives forces, and relationship between both indicate, that both depend on their space configuration and rheological behaviour, on contribution to viscosity, surface tension and stability influenced by many factors such as: molecule frequencies, shapes, sizes, interfaces processes, moisture content, biochemical, microbiological, enzymatic and water activities.

5. References

[1] Buczkowski R., Kleiber M. (1992). *Finite element analysis of elastic-plastic plane contact problem with nonlinear interface compliance*. J. of Theoretical and Appl. Mechanics, 4, pp. 855-883.

[2] Kokini J. L., Eads T., and Lederscher R. D. (1993). *Research needs on the molecular basis for food functionality*. Food Technology, 47, 3, pp. 36S-42S.

[3] Matuszek T. (1996). *Contact phenomena in the food systems*. Abstracts, 7th Symposium "Vibration in the Physical Systems", Poznań, Poland, pp. 202-203.

[4] Matuszek T. (1997). *Food systems network transformation based on the contact phenomena*. Proc., 1st Inter. Symposium on Food Rheology and Structure, Zurich, Switzerland, pp. 369-373.

[5] Matuszek T. (1999). *Mechanism of interactions and diffusion in the food microstructure systems*. Proc., The International Symposium on Trends in Continuum Physics, "TRECOP" 98, Poznan, Poland, World Scientific, Singapore, New Jersey, London, Hong-Kong, pp. 242-251.

[6] Matuszek T. (2001). *Principles of Measurements of Rheological Properties.* In: The Chemical and Functional Properties of Food Components. Sikorski Z. (Ed.), Technomic Publishing Company, Inc. USA.

[7] Matuszek T. (2008). *Dynamic characteristic of multifunction water molecule by analysing chosen dairy product microstructure*. Abstract of 14th World Congress of Food Science and technology, Shanghai, China, pp. 531-532.

[8] Matuszek T. (2009). *Water molecule expected localization in the food matrix and its interaction probabilities under food processes engineering conditions*. Proc. TH Inter. Symposium on Food Rheology and Structure, Zurich, Switzerland, pp. 604-605.

[9] Matuszek T. (2011). *Cleaning effectiveness and environmental criteria*. Journal of Hygienic Engineering and Design, Vol. 1, pp. 44-46.