A MULTIPARAMETRIC METHOD OF EVALUATION OF RHEOLOGICAL PROPERTIES OF SOLID FOOD PRODUCT

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SUMMARY

This method is based on inducing and evaluating deformation in a studied sample in a cycle alternating stress and relief with the stress increased in each cycle and sample relaxation possible during the relief period. As a result characteristic rheograms can be obtained. The rheograms can be used to obtain numerical values of constants of material coefficients of viscosity and elasticity modules. For simplification one can determine rheological parameters like: plasticity, elasticity, fluidity.

Introduction

Among numerous existing method of evaluation of mechanical properties of meat and its products none is generally accepted as optimal one. The most frequently used are one-parametric methods of measuring the stress needed to destroy a sample in shear - compression system, such as Lee-Kramer chamber or Warner-Bratzler system. These methods, however, cannot be used in case of small samples or samples of non-homogeneous structure, when parameters have to be determined for the specific section of the sample. In such cases, testing machines with probes that enable tests for specific location are being used.

Texture of the sample cannot be precisely determined using one-parametric methods, hence multiparametric method are needed. Testing is performed by inducing the programmed strains or deformation of the sample. The diagrams representing functional relationships are analysed according to rheology principles.

Significant progress in food texture analysis was marked after introduction of Texture Profile Analysis (TPA) in 1963 (Fridman et al. 1963; Szczesniak, 1963; Surmacka-Szczesniak, 1983).

One of the multiparametric methods, the Continuously Alternated Stress-Relax Analysis (CASRA) (Tyszkiewicz, 1970) is based on multiply tests of sample under wide range of stresses up to the moment of structure destruction. Its implementation was limited due to the time consuming procedure. In this paper, new automated version of this method is presented.

Principles of the method

Initially simple testing machine was equipped with blunt edge circular cross-section punch. The probe was loaded with lead weights which number was incremented during the test. After each stress cycle, relief period followed enabling sample relaxation. Stress pattern during the test is presented in fig. 1A. Recording of the probe displacement as a function of time produces characteristic rheograms. A sample rheogram is presented in fig. 1B.

Rheograms analysis and structure of the rheological model

Obtained rheograms can be analysed and from the shape of the curves and parameters obtained for characteristic points of the diagram important conclusions about the rheological structure of the samples can be drawn. For homogeneously structured meat products being tested, a comprehensive rheological model was proposed (presented in fig. 2), which for low stress lower than $\backslash_0$ not inflicting the structure destruction shows conformity with the Burgers model. From the rheogram, if the time of bites is long enough numerical values of the modulus of elasticity as well as coefficients of viscosity can be obtained. Analysis of the variability of those parameters brings a lot of information about the rheological structure of the tested materials, but synthetical parameters are needed to characterise the samples tested on the mass scale.

For this purpose three parameters were proposed: fluidity F, elasticity E and plasticity P. Method of obtaining the values of those parameters from the rheograms is shown in fig. 3.A. Plasticity P is the most important parameter and it is defined as a stress needed for the structure break-down. This value - yield point τ_0 can be obtained directly from the rheogram. This point can be located at the inflexion point of the envelope limiting the curves reflecting boundary locations of the probe. In case of multiply internal structures within the sample the evaluation of the critical stress is difficult. Such case is presented in fig. 3B. Tests were performed on frankfurters manufactured with the significant amount of the collagen emulsion derived from pig skins.

Automated version of the method

Automatisation of the method was possible after Universal Testing Machine model 1445 has been introduced. This apparatus is characterised by high beam velocity, which allows program rapid change with a possibility to treat the change as a jump function. Rheograms presented in fig. 3AB were obtained using following program parameters:

- beam velocity between the bites - 120mm/min,
- beam velocity during the bite - 2mm/min,
- unit stress - 0,2N,
- stress increment - 0,2N for each next bite,
- duration of stress and relaxation periods - 15s each.

Applicability of an Universal Texture Analyser TA-XT2 was also evaluated. Standard software do not allow to implement the test program with the incrementally increased stress. Program parameters have to be reset for any consecutive bite. Rheogram showing the relationship stress vs strain for consecutive bites is presented in fig. 4. Synthetic parameters: elasticity E, fluidity F and plasticity P can be obtained with the similar accuracy as in test performed with use of Zwick apparatus. It is, however, necessary to utilize the type of probes required for this method. It would be useful to develop necessary software in order to incorporate CASRA method related procedures into library of computerised control system of this apparatus.

Probe shape selection

In the initial version of the method circular cross-section probes were used. However, it was concluded that reproducible and comparable results can be obtained only if the same probe is used during the entire test. Bourne, (1966) using blunt edge rectangular probe, ascertained the linear relationship between the force applied and distributions of the compressing force over the contact surface and cutting force along the length of the edge. In case of circular cross-section probe, the contact surface areas is dependent on the radius square, while there is linear dependence between cutting edge length and probe radius. Thus depending on probe diameter different effects dominate: for small diameter probes - cutting effect, whereas for large diameter probes - compression effect. In order to improve the reliability of the method and to ensure the similarity of the test conditions the range of rectangular probes was developed. The shorter size of the probe remains constant 2mm whereas the longer is changed stepwise from 4mm to 20mm in 2mm increments.

Influence of the probe dimensions on the results

Described method with use of modified probes was implemented to determine the plasticity P, elasticity E and fluidity F parameters of the same product - model butcher's meat with the homogenous stuffing. Results are presented in table 1. These results show diversified influence of the probe dimensions on the test results. Influence is significant for the smallest probes: 2x4 and 2x6mm. For the probes: 2x8, 2x10, 2x12, 2x14, 2x16, 2x18 and 2x20mm influence can be considered negligible. Considering the fact that the method is intended for use also in case of meat and meat products of non homogenous structure it is recommended that same probe with dimensions adjusted to the size of sample should be used during one test. This ensures the reproducibility of test results.

Evaluation of the measurement accuracy for rheological parameters

Method described above was used to determine the plasticity, elasticity and fluidity of 3 batches of frankfurters manufactured by different meat processing plants. Each batch consisted of 5 frankfurters, each frankfurter was represented by 4 cylindrical samples with height of 15mm and diameter ca. 24mm. Calculation were performed using of variance method ANOVA assuming error variance as a measure of the method's accuracy. Obtained results are presented in table 2.

Conclusion

1. The method presented is useful for determination of rheological properties of meat and meat products within the full range of stress up to destruction of sample structure. By means of compression/cutting test maximal structure elasticity (elasticity), degree of viscosity irreversible structure changes (fluidity) and critical strength of structure (plasticity) can be determined.

2. Reproducibility of test on sample with homogenous structure is achieve using the probes with rectangular contact surface with the smaller size 2mm and longer size within the range 8-20mm. For meat with the natural tissues layout and non-homogenous meat products it is recommended to perform the test using one probe with dimensions adjusted to the size of sample. In case of meat, to improve the reproducibility of results, it is recommended to position the longer size of the probe perpendicular to the fibres.

3. The accuracy of determination of the synthetical parameters: plasticity P, elasticity E and fluidity F was evaluated. Tests were performed on model product - frankfurters.

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Table 1 Effect of punch size on rheological parameters,
Table 2 Precision of CASRA method
Fig. 1 Stress and strain distribution during test,
Fig. 2 Rheological model for homogenously structured meat products,
Fig. 3 Methods of obtaining the values of plasticity P, elasticity E and fluidity F,
Fig. 4 Rheogram of sausages frrom the Universal Texture Analyzer TA-XT2.