PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 14 (11): 837-840, 2015
ISSN 1680-5194

Consistency Cone Penetrometry for Food Products

Aitbek Kakimov, Zhanibek Yessimbekov, Aigerim Bepeyeva, Bolat Kabulov and Zhainagul Kakimova
Shakarim State University of Semey-071410, Kazakhstan

Abstract: This study describes the operational principle of cone penetrometers and method of determining the yield stress using cone penetrometers. The standard GOST R 50814-95 "Meat products. Methods of penetration determination by means of the cone and the needle indentor", developed by the Russian Federation in 1995, applies to viscous-plastic (meat and sausage forcemeat, pate) and elastic (ready meat and sausage) meat products and specifies the methods of consistency determination by cone or needle penetration. The test method for penetration of viscous-plastic materials using different penetrometers and the main equations for yield stress determination are presented.

Key words: Penetrometer, yield stress, cone, indentor, minced meat

INTRODUCTION

Food products are complex multicomponent disperse systems, with specific physical and chemical properties and structure, which are formed its rheology (or structural-mechanical) properties (Rao, 1999). Engineering rheology, studying the mechanisms of structure formation and structural-mechanical properties of food products and development of the methods and devices, plays a significant role during the processing and monitoring of quality of food products (Machikhin, 1990). The structural-mechanical characteristics describe the resistance of meat samples to the mechanical stress and represent the fundamental physical properties of meat products. The main structural-mechanical properties are compression, shear and surface properties (Gorbatov, 1979; Kosoy *et al*., 2005). The yield stress is classically defined as the threshold stress to initiate flow (Steffe, 1992; Sun and Gunasekaran, 2009). Yield stress measurement is the main rheological parameter to mind during the formulation of meat products.

The most fundamental methods of controlling food consistency are rotational rheometry and penetrometry. Rotational methods allow automated quality control for minced meat. Penetrometry is universally available and allows quick and accurate measurement of consistency of raw material, semi-finished and ready products. Penetrometers can more fully characterize the structure and shear phenomena in minced meat and sausages. Comparing with plastic and effective viscosity, yield stress is more sensitive to changes in technological (moisture, fat content, pH) and mechanical (mincing, mixing) factors (Yerkebaev *et al*., 2006; McKenna and Lyng, 2008).

A penetrometer measures the penetration depth of an indentor of specified size and shape, under a specified constant load, into a flat material surface. The most common indentor shape is the cone and for this, the method is called cone penetrometry. Cone penetrometry is thus standardized by specifying the cone angle and the constant load. Penetrometers are simple in construction and the procedure takes 5 to 180 s for determining penetration depth, shear stress and yield stress. At the moment of loading the yield stress has its maximum value, but further penetration decreases the yield stress and during the flow it's not changed (Gorbatov, 1979; Kosoy *et al*., 2005).

Penetrating method is also appropriate to analyze the consistency of ready sausages and meat products. From the penetration depth, the shear stress is calculated. Moscow Institute of Applied Biotechnology developed and implemented the standard GOST R 50814-95 "Meat products. Methods of penetration determination by means of the cone and the needle indentor". This standard was developed by the Russian Federation in 1995 and applies to viscous-plastic (meat and sausage forcemeat, pate) and elastic (ready meat and sausage) meat products and specifies the methods of consistency determination by cone or needle penetration.

The cone indentor for sausage forcemeat is 45-60 mm long with a cone vertex angle of $2\alpha = 60°$ and $2\alpha = 10°$ for ready sausages (Fig. 1) and made of aluminium or other material which is non-hazardous for food products. The sample of forcemeat is first filled into the container and slightly pressed leveling the sample surface. Then the container is placed in an air or water bath at 20°C for until equilibration (20±0.5)°C. Next, the measurement is performed in accordance with the operational instructions of the device. After completing the measurement, the value of yield stress is calculated using specific formula, for minced meat:

$$\sigma_0 = kmh^{-2} \tag{1}$$

Corresponding Author: Zhanibek Yessimbekov, Shakarim State University of Semey, 20 A Glinki Street, Semey-071410, Kazakhstan

σ_0 : yield stress, Paa
m : mass of cone with stock, kg
h : penetration depth for 180 s, m
k : constant for cone, k = 2.1 N/kg if $2\alpha = 60°$

For meat products (sausages):

$$\sigma_0 = Ph^{-2} = mgh^{-2} \tag{2}$$

P : force, N
m : mass of cone with stock, kg
h : penetration depth for 180 s, m
g : standard acceleration of gravity, m/s^2

Cone penetrometers: Cone penetrometry is widely used in food technology. The common penetrometers used in Kazakhstan are mostly manufactured in Russia. The Moscow Technological Food Processing Institute developed a compact penetrometer (Fig. 3). This device consists of base 1, to which the moveable platform 2 and vertical stand 3 are installed. The clamp 12 and sensor 11, bracket 7 on the rod 6 and blocks 5 are attached to the vertical stand. The blocks put the wire in tension. At the wire end, the moveable rod 10 of the sensor 11 is installed. The plate 9 for installing the additional load and indentor 14 are installed on the rod. At the other wire end, the load 4 for balancing the mass of rod with plate and indentor is applied. At the bottom of the clamp, the mechanical stopping device 13 is attached. Conical indentors with vertex angles of 30, 45, 60, 90, 120° and disk plates are used.

To measure with a given penetrometer, we must first connect the wires and then the rod with selected indentor is moved to and locked in the end position. Next, we adjust the pointer to the last point of the scale. Then the stopper is removed and the rod is gently displaced downward against the stop and the pointer is zeroed. Next, we calibrate the device. The food sample is then placed on the platform and the platform is raised until the indentor first contacts the sample. Next, the specified weight is mounted on the plate and the stopper is removed. After a certain time, the system is balanced and the scale readings are taken.

Penetrometer PPM-4, designed by Research Center named after M.V. Keldysh and Moscow State University of Applied Biotechnology, is used to measure the dynamic yield stress of elastic products (including dry sausages on the various production phases). This is a hand held portable penetrometer. After achieving the predetermined resistance force of the product, the indentation depth is shown on the display. There are four spring suspensions, mounted in the drum, which allow the detection limit of the rheological parameters to be changed.

The "Structurometer" was made in the scientific-production company "Radius" (Moscow, Russia). It is used to measure rheological parameters of food in various fields of the food industry. The Structurometer consists of a controller, measuring head and a set of indentors and tools (Fig. 5).

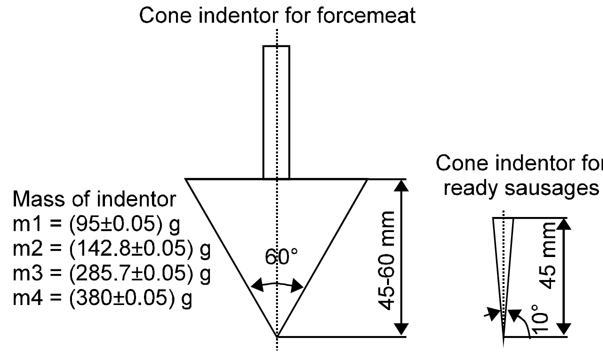

Fig. 1: Cone indentors for meat products

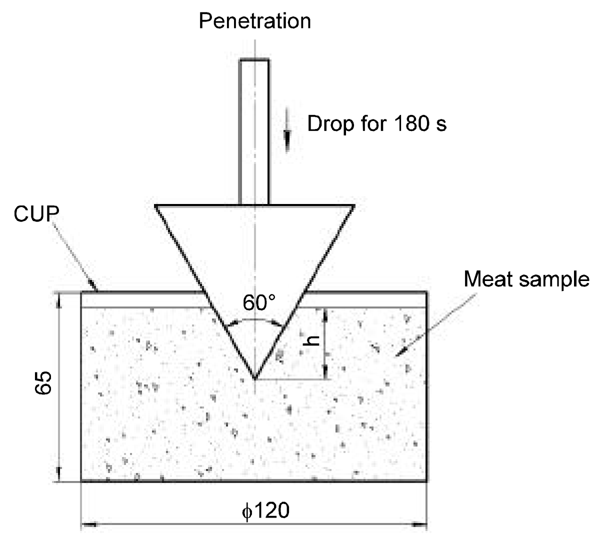

Fig. 2: Penetration scheme

The electromechanical gear motor of the "Structurometer" consists of step motor 2, helical gears 3, screw 4 and nut 5 and control unit 6 including a digital display with keyboard all mounted into the case 1. Screw 4 is rigidly attached to the platform 7 and, with its stepper motor, the platform can move vertically with constant speed. Above the platform 7, the measured head is mounted and then moved along the vertical rod 9 and secured by a screw 10. Screw 11 is used to mount the indentor 12 into the measurement head. Inside the measurement head the tensometric beam is positioned, to digitize the imposed load on the indentor. The operation principle is based on penetration of stationary indentor to the sample, moved up by constant speed for determination of rheological properties of materials of food industry.

Since the "Structurometer" displays the load and also the penetration depth in mm, the Eq. 1 transforms into the dimensional Equation:

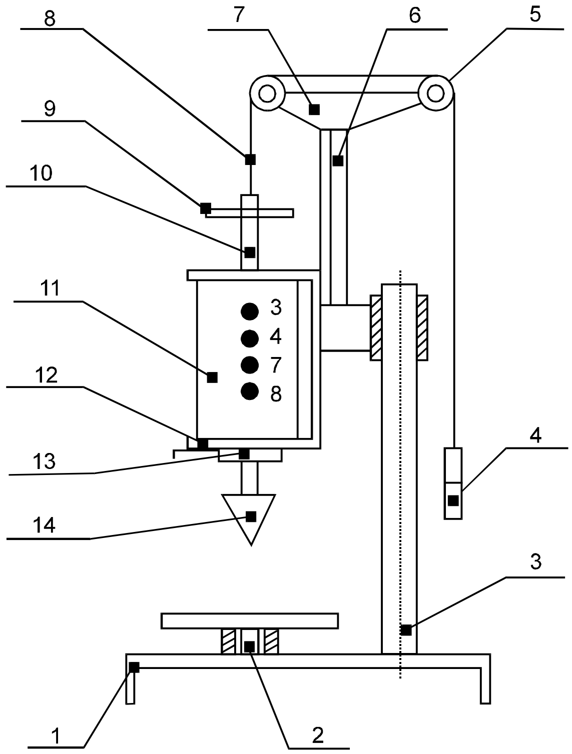

Fig. 3: Small-sized penetrometer. 1: Base, 2: Moveable platform, 3: Vertical stand, 4: Load, 5: Block, 6: Stand, 7: Bracket, 8: Wire, 9: Plate, 10: Moveable rod, 11: Sensor, 12: Clamp

$$\sigma_0 = K \cdot \frac{P \cdot 9,81.10^3}{h^2}, \text{Pa} \qquad (3)$$

where, P is the indentor load to the sample, g.
Consequently, the cone constant is given by:

$$K = \frac{\cos^2(\alpha/2)}{\pi \cdot tg(\alpha/2)} \qquad (4)$$

where, α - angle at the vertex of the cone ($\alpha = 45°$ H α = 60°). The arithmetic mean of the yield stress, for each variant of sample is then calculated.

Most of the technological processes in the food industry are related to the mechanical impact on the processing product. Structural-mechanical (rheological) properties qualitatively and quantitatively determine the product behavior under the influence of external factors and are linked to the stress and deformation in the loading process. Depending on the loading condition, for the same product, different rheological properties result. Knowing the rheological properties of the meat and meat products is required, not only for evaluating the quality of the product, but for designing and developing new technological equipment and optimization of the technological process. Introduction of rheological methods for controlling the different technological processes of food production, will allow stabilization of food product quality and reductions of processing time or of energy consumption.

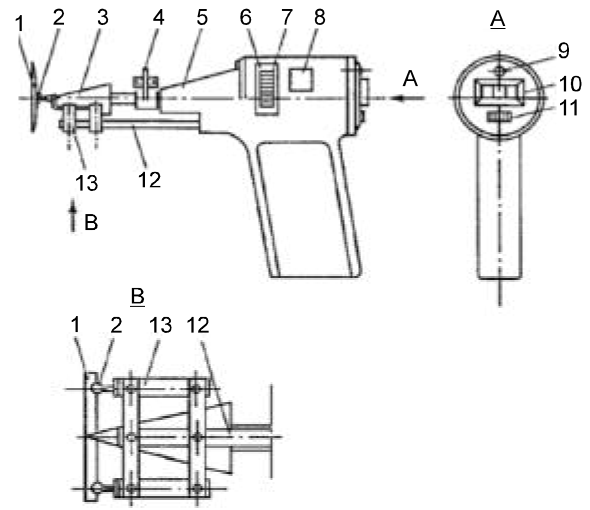

Fig. 4: Penetrometer PPM-4. 1: Support, 2: Ball support, 3: Indentor, 4: Rod, 5: Casing, 6: Window of drum, 7: Drum, 8: Display of force controlling, 9: Light indicator, 10: Light-digit indicator, 11: Power switch, 12: Moveable rod, 13: Articulated mechanism

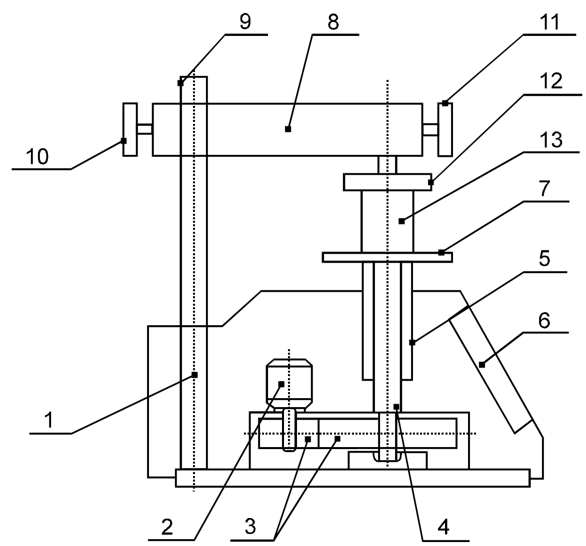

Fig. 5: Penetrometer “Structurometer”. 1: Case, 2: Step motor, 3: Helical gears, 4: Screw, 5: Nut, 6: Control unit, 7: Platform, 8: Measuring head, 9: Rod, 10: Measuring head mounting screw, 11: Indentor mounting screw, 12: replaceable indentor, 13: Food sample

ACKNOWLEDGMENTS

This article was prepared as part of the scientific project No1064/GF4 of the Ministry of Education and Science of the Republic of Kazakhstan. We thank Professor A. Jeffrey Giacomin of the Polymers Research Group of the Chemical Engineering Department of Queen's University for his help with the manuscript.

REFERENCES

Gorbatov, A.V., 1979. Rheology of meat and milk products. M.: Pishevaya promyshlennost, pp: 384 (In Russian).

Kosoy, V.D., A.D. Malyshev and S.B. Yudina, 2005. Engineering rheology in sausage production. M.: KolosS, 264 p (In Russian).

Machikhin, Yu. A., 1990. Rheometry of food materials and products: Handbook., M.: Agropromizdat, 271 p (In Russian).

McKenna, B.M. and J.G. Lyng, 2008. Introduction to food rheology and its measurement. In: Texture in foods Volume 1: Semi-solid foods. Woodhead Publishing Limited, Cambridge, pp: 130-160.

Rao, A., 1999. Rheology of fluid and semisolid foods: Principles and Applications, Aspen, Gaithersburg, Md, USA.

Steffe, J.F., 1992. Yield stress: phenomena and measurement. In advances in food engineering; Singh, R.P. and Wirakartakusumah, M.A. Eds., CRC Press, London, pp: 363.

Sun, A. and S. Gunasekaran, 2009. Yield stress in foods: measurements and applications. Int. J. Food Properties, 12: 70-101.

Yerkebaev, M.J., T.K. Kulazhanov and Ye. B. Medvedkov, 2006. Bases of rheology of food products: manual, Almaty, pp: 298 (In Russian).