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DETERMINATION OF TEXTURAL PROPERTIES OF DIFFERENT KINDS OF KETCHUPS OF TWO DIFFERENT RATES UNDER DIFFERENT CONDITIONS OF STORAGE FOR THE DETERMINATION OF THEIR CONSUMAL QUALITY

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ABSTRACT
The aim of this work is an evaluation of structural properties of ketchups originating from five different producers at two different batches and consecutively their comparison in different storage conditions and a determination of their consumable quality. Using the objective instrumental method based on physical deformation of the sample we evaluated properties like, viscosity and consistency of ketchups on texturometer TA.XT plus (Stable Micro Systems, Godalming, United Kingdom). These tests were completed on the basis of regressive extrusion using a hyperbaric disc. The consistency of each ketchup from the first rate determined by regressive extrusion ranged from 2656.82 $g.s^{-1}$ to 5137.37 $g.s^{-1}$. The lowest value 2656.82 $g.s^{-1}$ was found in the sample A after 3 days of storage at the temperature 5 °C, the highest value 5137.37 gs^{-1} was found in the sample C after 10 days of storage at the temperature 5 °C. The value of the consistency in each of the samples didn´t change much, not even after the ketchups were stored at a room temperature for 24 hours. The consistency of each of the ketchups from the second rate determined by the regressive extrusion ranged form 2700.14 $g.s^{-1}$ to 5133.94 $g.s^{-1}$. The lowest value 2700.14 $g.s^{-1}$ was found in the sample A after 10 days of storage at the temperature 5 °C, the highest value 5133.94 $g.s^{-1}$ was found in the sample C after buying in a market and consequential cooling to 5 °C. The value of the consistency in each of the samples didn´t change much, not even after the ketchups were stored at a room temperature for 24 hours. The results obtained from the evaluation of the texture can be used to optimize the production and thereby prolonging the duration of maintaining its characteristics during the period of minimum durability.

Keywords: texture; *TA.XT plus*; ketchup; consumer

INTRODUCTION
Ketchup is a tomato puree seasoned with spices. It´s usually made of tomato puree and flavoured with salt, sugar, vinegar, oil but also onion, garlic, mushrooms, spice, aromatic herb essence and other additives improving colour, taste and consistency **(Stýčková & Teslíková, 2005)**.

Usually at least 6% of dry matter should come from fresh tomatoes or tomato puree. Glucose or glucose syrup makes 20 - 30% of the total solids. The high glucose content and high dry matter content in ketchup leads to a reduction of water activity on the level from 0.93 to 0.95. The amount of added vinegar results in 0.8% and 1.0% acetic acid in the product. Spices can be replaced with oleoresins or extracts. Often starch is added to achieve the desired consistency. However, some countries don´t allow this. In these countries the final product is referred to as a „tomato sauce“. To achieve a certain durability of a closed product benzoic acid and sorbic acid are used for preservation. Durability of a closed product is then approximately a year, whereas a durability of an open product is a few weeks or months provided it is kept at a safe temperature depending on the structure and the presence of preservatives **(Lund et al., 2000)**.

The ketchup is required to be a clear tomato colour, smooth looking, without any blots with a consistency that is neither too waterish nor too compact so that it doesn´t spurt or separate the liquid part from the solid after shaking and then opening the bottle. Also, there must be a pleasant ketchup fragrance preserved **(Ranken et al., 1996)**.

The production of ketchup uses a so-called „hot break“ process. It means that the tomatoes are very quickly warmed up to at least 77 °C but usually 90 °C. At this temperature enzymes begin to sunder which preserves a higher pectin level. It means that by destroying all the enzymes using a „hot break“ process a more viscous product is made, less susceptible to separation. There´s also a „cold break“ process in which the tomatoes are warmed up to 65 °C. The pectin is destroyed and therefore a more sparse liquid is made with a brighter colour and a fresher taste **(Pritchard & Burch, 2003)**.

In food processing, food scientists add special ingredients for the textural properties of food. Starches, pectin and rubber are added for the purpose of thickening, gel consistency or to increase viscosity. The addition of glucose affects the texture of food by improving the sensation in mouth or it may be added in a higher concentration so the food is more chewable and insubstantial because crystallization is in progress. Viscosity and consistency are interesting properties, which affect the textural as well as the visual attributes of food quality **(Vieira, 1996)**.

The effect of processing on the texture of the product can be better understood after considering the structural changes within the process of manufacturing, when the tomatoes are cut, warmed up and homogenized and the cell and cell-wall disperse arises, which affects the textural properties of the ketchup **(Ouden, 1996)**.

Consistency and the level of serum separation largely determine the quality of the ketchup. Consistency of the ketchup depends directly on the rate of the tomato pulp used in the production, whilst the serum separation depends on the heat used. There are demonstrable differences in viscosity of the ketchups produced by „hot break" and „cold break" methods (**Marsh et al., 1997**).

The term „consistency" refers to non-newtonian fluids with dispersed particles and dissolved long-chain molecules. Usually the product flow is measured. Newtonian fluids are characteristic by their static viscosity. Their deformation is directly proportional to the pressure used, whilst on the other hand we know non-newtonian fluids, including ketchup, which we characterize as pseudoplastic fluids. Here the viscosity decreases with the pressure and the heavier we affect the simplier it deforms. It follows that ketchup is a highly viscous substance and flows slowly at a slow pressure **(Fishman et al., 1991)**.

The consistency of tomatoes and products depends on the presence of intact cells and cell fragments, pectin substances on their surface, the solubility of pectin and suspended particles in serum. Insoluble constituents present in these products may be intact, frangible or pulverised cells and cell fragments and long chains of lignin polymers, cellulose and hemicellulose and pectin constituents insoluble in water. These dispersed particles are highly hydrated and they take up considerably large content, however, they contain very few solid constituents. Consistency depends primarily on the ratio of water-insoluble substances to total solid substances **(Kertesz and Loconti, 1994)**.

Viscosity has been described as a resistance to motion when mixing or pouring ketchup. Ketchup is an excellent example of flow properties. When the ketchup bottle flips upside down, its contents will remain in its place for a while. On the other hand, if the content was mixed and shaken before flipping, it would immediately start flowing along the sides of the bottle as a relatively sparse fluid. The viscosity of the ketchup is defined as an internal friction of the motion, when it easily arises the motion (i.e. liquid materials) but only a small friction arises. In reverse, for solid materials the friction is relatively high **(Beckett, 2004)**.

Density has a great influence on the taste since denser ketchup remains in the mouth longer and releases its flavour slowly. Moreover, the longer it stays in mouth the more it heats and releases more volatile compounds. Approximately 95% of the ketchup consists of smaller molecules like water, vinegar, sugar, salt and aromatic compounds. The remaining 5% consist of larger molecules like polysaccharides, most of which are starch and fibres. These have an ability to hold a large amount of water, which results in a bigger density of a ketchup. Pectin is the examples of larger molecule, which is naturally found in fruits and vegetables, where this molecule holds together the cell walls. Pectin is released from the cell walls during the boiling and its amount depends on the degree of ripeness of the fruit or vegetable. Pectin has been found in ketchup extracted from the tomatoes, however it hasn´t been able to hold a larger amount of water. One of the solutions is the decrease of water by further boiling, however this makes the texture „thicker" and less desirable. Another solution is the addition of larger molecules, which hold the water in the ketchup. That is why ketchups are being added different kinds of polysaccharides, which prevent from larger losses of water and therefore sustain a fitting texture of the product **(Vega et al., 2012)**.

During the storage and the transport some undesirable changes can occur. Partly because the product hasn´t been in a thermo-dynamical balance when leaving the production line and partly because of the fluctuating temperature within the storage and transport. These changes can result in the fault of the product, caused by structural changes of the product **(Kilcast, 2003)**.

Within the storage the viscosity of the product may be changed. As the ketchup homogenizes within the production process, an increase of apparent viscosity occurs up to 40% regardless of the processing temperature or homogenisation pressure **(Race 1991)**. It means that all the homogenised products are in advantage within the storage, therefore even after expiration of some time the viscosity remains unaffected.

Szczesniak (2002) explains the texture as a sensory and functional demonstration of structural and mechanical and surficial properties of food, which we perceive sensually (vision, hearing, feel, kinesthesis composed of sensation of the presence of motion and location) and which affect the nervous receptors. Complex and dynamic character of the texture is evaluated analytically by a sensory analysis.

The texture properties of ketchups have an important meaning in a number of technological operations. Understanding of the basic texture properties such as viscosity is important not only in characterising the raw material, but also in a number of technological calculations or supervision of processing devices. This results in a development of texturometry, which helps to increase the competitiveness of the products in the markets. Texturometer is one of the possibilities to evaluate the texture of foods and even though it´s an instrumental method in which the device imitates the human senses and measures the basic mechanical properties, only humans can evaluate the quality completely, by their sensory rating. However, the device measuring the attributes related to texture and quality are necessary for research and supervision of foodsstuffs **(Kilcast, 2003)**.

Texturometer *TA.XT plus* (Stable Micro Systems, Godalming, United Kingdom) is basically able to measure any physical property of the product. It´s very effective and capable of making high-speed testing. It´s also very easy to use. In connection with the software, the device is well projected, constructed and made by the company Stable Micro System for a long-term reliability and exactness.

The relationship between the instrumental measurement of the texture and sensory evaluation is still an object of examination. Instrumental methods imitate human testing methods or measure the basic mechanical properties or indirectly set optical and chemical properties. Only humans can evaluate the quality with a sensory evaluation, however the devices measuring the attributes related to quality are necessary for research and supervision **(Abbott et al., 1997)**.

MATERIAL AND METHODOLOGY

During the work, the texture properties of ketchups originating from 5 different producers were studied. We compared 2 different production batches, bought in the market (A-E) (Tab. 1). These properties were measured by a texturometer *TA.XT plus* (Stable Micro Systems, Godalming, United Kingdom). This device was projected by the company Stable Micro System for the measurement of texturometrical properties of commodities like foodstuff, cosmetics, pharmaceutical products and different industrial materials.

This device continually records the force, distance and a time whilst simultaneously deforming the material with pressure or tensile force. Deformation of the sample placed on the base of the device is carried out by a fluctuant arm with a strain gauge to record the acting force. There are different extensions and probes attached to the arm and the base of the strain gauge. The process of measurement is recorded by the PC program *Exponent* (Stable Micro Systems) in a form of deformation curve. This sophisticated PC program allows further curve processing such as statistical evaluation of the recording (determination of the maximum, minimum and average values, standard deviation and coefficient of variation of the endpoint). Mathematical calculations (labeling the maximum and minum of the curve, calculation of the extent below the curve, determination of the maximum, minimum and average curves as well as the comparison with remaining curves, saving the recordings and their further processing. This allows us to watch the measured material within a certain time period.

The device works on the base of its setting given by its user. The handeling is defined according to the chosen mode (measurement of the force or path during the pressure or tensile force) and the conditions of the adjustable parameters (Pre Test Speed, Test Speed, Post Test Speed, Distance, Force, Time, Trigger). Utility is designed so that the user can save all the parameters and settings for the next measurement as a routine again. The usage of the device is simplified to minimum using the projects in the program in which there are parameters adjusted for each commodity.

In this case, we used the adjustment of those Exponent projects in which the ketchups were evaluated by back extrusion using the A/BE probe. This device consists of a disc made of plexiglas. The disc penetrates centrally into the ketchup in the pattern book and pushes the ketchup up and round the edge of the disc by a pressure test.

This probe is appropriate for measuring viscosity and product like soft gels, processed fruits and vegetables, ointments, sauces. There are discs of 3 different sizes. The selection of the disc depends on the measured product. In our case we´ve chosen a disc with the diameter of 45 mm. To determine the texture properties we used ketchups coming from five different producers A-E (Tab.1) and two different batches, we monitored the changes within the storage of both batches during 12 days immediately after the opening of the ketchups, after 3 days of storage at 5 °C, after 7 days of storage at 5 °C, after 10 days of storage at 5 °C and consecutively after 24 hour storage at room temperature. Furthermore, we compared 2 ketchups (soft and hot) after the expiration date with 2 ketchups (soft and hot) before the expiration date. The changes within the storage were monitored in 14 samples. 5 samples from the first rate were measured twice within every evaluation. The other 5 samples from the second rate as well. Consecutively, 2 samples before the expiration date were compared to the 2 after the expiration date, which were also measured twice. Altogether there were a hundred measurements made and consecutively evaluated.

The measurements were carried out at same times (10 A.M). We tested the ketchups in common sample books with a diameter of 45 mm. The sample book was filled app. to 75% of its height. We measured each ketchup twice within every measurement to achieve better results. The content of the sample book was cooled to a fridge temperature of 5 °C each time. There was a probe used with each test. The probe was placed centrally above the sample book which was placed of the board where it fitted exactly to avoid the movement of the sample book during the lifting of the probe. We used software *Exponent* (Stable Micro Systems) preprogramed adjustments for ketchup testing. We started the measurement using the command „run test“. From the first contact with the ketchup the probe continued to a depth of 30 mm. As soon as this depth was achieved, the probe began to lift to its original position. During the penetration of the probe into the ketchup, the program *Exponent* recorded the measurement in a form of a curve. This curve depicted all the properties we monitored such as rigidity, consistency, cohesion and viscosity. As soon as the test was carried out, all the sample readings were recorded.

The results of the measurements of ketchups´ texture properties (consistency, viscosity) we expressed graphically in *MS Excel* (Microsoft, Redmond, Washington, USA) and using the matematical and statistical analyses: arithmetic mean (x) , standard deviation (sd), coefficient of variation (c.v).

Statistical evaluation of the results were carried out in the program *Tanagara 1.4.43*. (Rakotomalala, Lyon, France). Based on the parameters arised from our results, we chose a nonparametric statistical test Kruskal-Wallis 1-Way ANOVA.

Consistency: The area in the positive part of the graph. The higher is the value, the greater is consistency of the sample. The consistency relates to non-newtonic fluids with dispersed particles and dissolved long-chain molecules. Usually the product flow is measured.

Viscosity: The area in the negative part of the graph determines the viscosity index. Viscosity is a physical property of food, defined as the flow rate of the unit of force. The higher is the value, the greater is viscosity of the sample.

Table 1 Samples of ketchup used to measure

Sample	A	B	C	D	E
Type	Fine ketchup with alternate sweetener	Spicy ketchup with chili	Sweet ketchup	Spicy hot ketchup	Fine ketchup
Composition	Tomato paste, drinking water, fermented vinegar, salt, modified corn starch, citric acid, spice mix, xanthan gum, sucralose.	Drinking water, tomato paste, isoglucose syrup, vinegar fermentation, modified starch E1422, salt, spices (0.07% chili).	Water, concentrated tomato paste, sugar, fermented spirit vinegar, modified starch, salt, condiments (pepper extract).	Tomatoes, fermented vinegar, sugar, salt, herbs, spices kajanské, herbal extracts (contains celery), spices, spice extract.	Water, tomato concentrate (28%), sugar, fermented vinegar, modified starch E1422, salt, sodium benzoate, potassium sorbate, natural flavor.

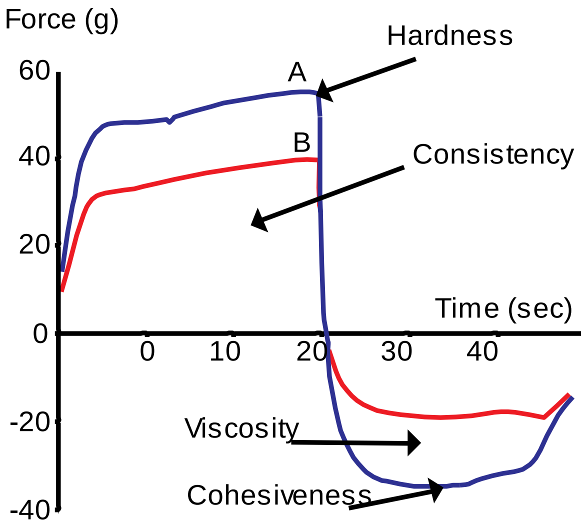

Figure 1 Curve showing the textural properties of ketchup in the program *Exponent*

RESULTS AND DISCUSSION

The consistency of each ketchup from the first batch determined by regressive extrusion ranged from 2656.82 g.s^{-1} to 5137.37 g.s^{-1}. The lowest value 2656.82 g.s^{-1} was found in the sample A after 3 days of storage at the temperature 5 °C, the highest value 5137.37 g.s^{-1} was found in the sample C after 10 days of storage at the temperature 5 °C. The value of the consistency in each of the samples didn´t change much, not even after the ketchups were stored at a room temperature for 24 hours (Fig. 2). The consistency of each of the ketchups from the second batch determined by the regressive extrusion ranged form 2700.14 g.s^{-1} to 5133.94 g.s^{-1}. The lowest value 2700.14 g.s^{-1} was found in the sample A after 10 days of storage at the temperature 5 °C, the highest value 5133.94 g.s^{-1} was found in the sample C after buying in a market and consequential cooling to 5 °C. The value of the consistency in each of the samples of second batch didn´t change much, not even after the ketchups were stored at a room temperature for 24 hours (Fig. 3).

Ketchup is a food with a thin consistancy so within its production there are various additives added in order to improve this property **(Sinha, 2011)**.

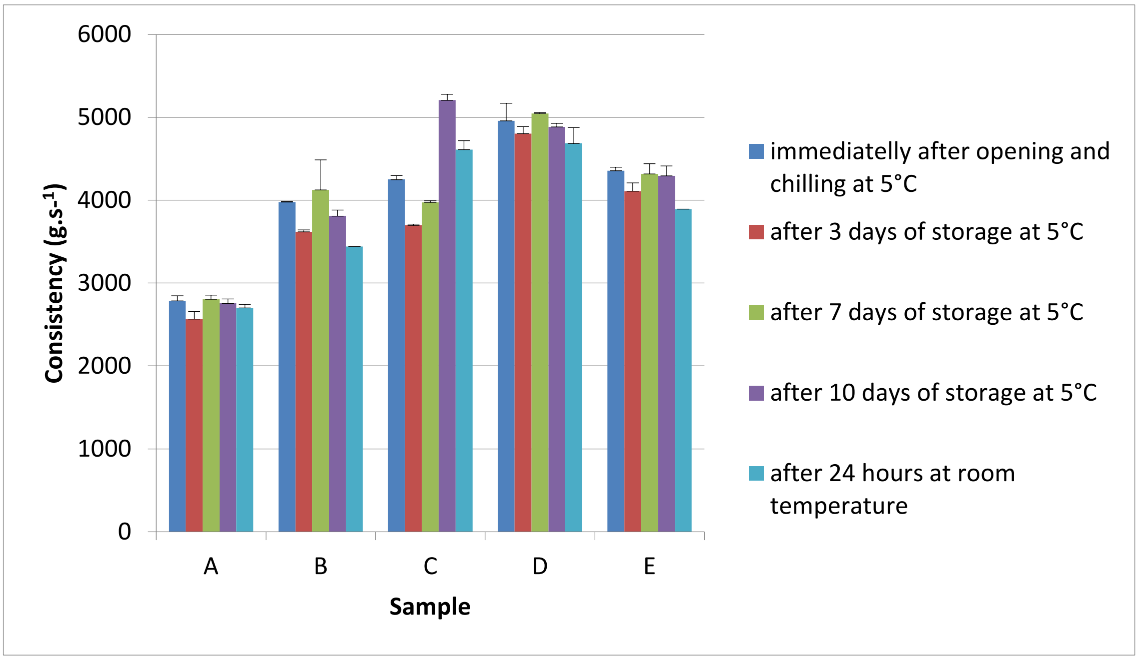

Figure 2 The average values of consistency for each of ketchup A-E of the first batch depending on storage

The graph shows the average value of the consistency of ketchups of the first batch (sample A – E), depending on storage, where fault segments with standard deviation is shown.

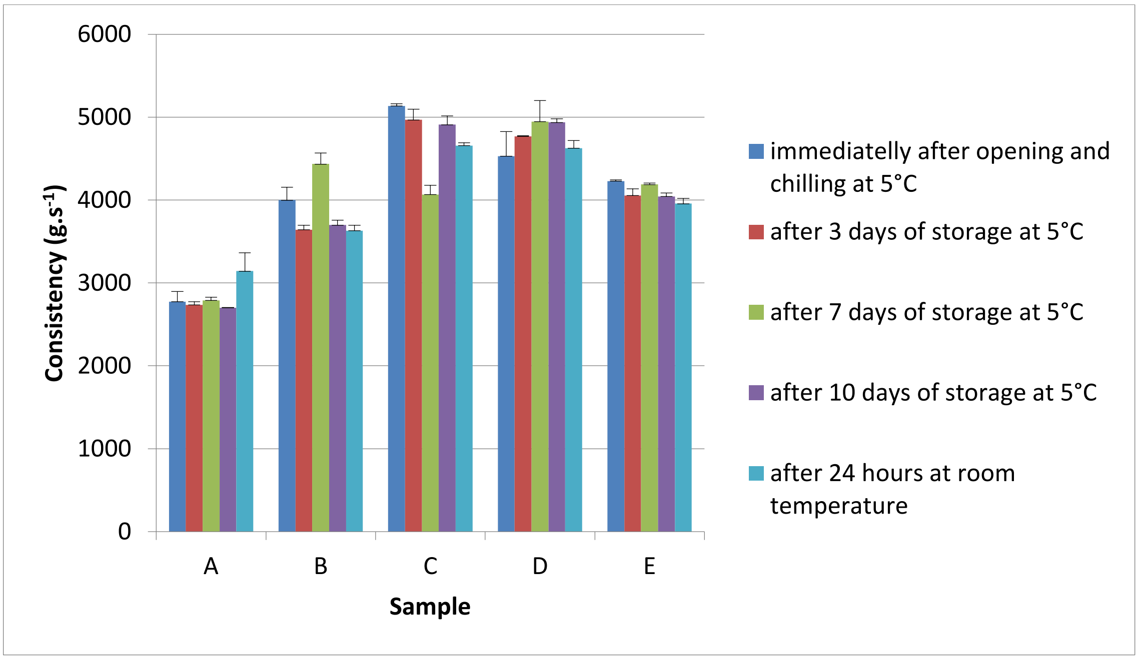

Figure 3 The average values of consistency for each of ketchup A-E of the second batch depending on storage

The graph shows the average value of the consistency of ketchups of the second batch (sample A – E), depending on storage, where fault segments with standard deviation is shown.

The consistency of ketchups depends on the presence of intact cells, cell fragments and pectin substances as well as on the solubility of these in a serum. Consequently it arises that the consistency depends on the ratio of the water insoluble substances to the number of solids **(Kertesz and Loconti, 1994)**.

Marsh et al. (1997) found out that the consistency of the ketchup depends directly on the rate of the tomato pulp used in the production, and also on whether there was any thickening used. Besides the additives used, glucose may be used as a thickening **(Marsh eta al., 1997)**.

Table 2 Statistical comparison of the consistency of the first and second batch of ketchup A-E

Storage conditions	*p* - value
Immediately after opening and chilling 5 °C	0.004223
After 3 days of storage at 5 °C	0.004223
After 7 days of storage at 5 °C	0.003077
After 10 days of storage at 5 °C	0.001545
After 24 hours at room temperature	0.001637

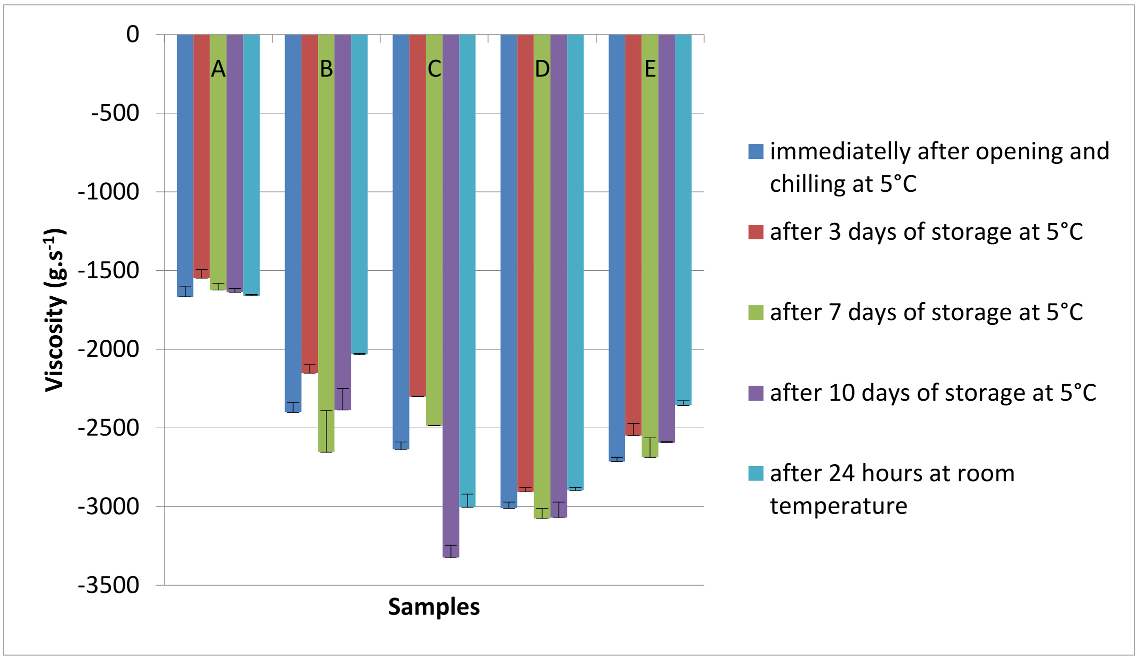

Figure 4 The average values of viscosity for each of ketchup A-E of the first batch depending on storage

The graph shows the average viscosity of ketchups of the first batch (sample A – E), depending on storage, where fault segments with standard deviation is shown.

After applying a nonparametric statistical method Kruskal-Wallis 1-Way ANOVA 1 to compare the consistency of the first and second rate of ketchups A-E, it´s safe to say that there´s a highly significant statistical difference between them at different storage conditions, where $p < 0.01$.

The viscosity of each ketchup from the first batch determined by regressive extrusion ranged from 1548.38 $g.s^{-1}$ to -3323.77 $g.s^{-1}$. The lowest value -1548.38 $g.s^{-1}$ was found in the sample A after 3 days of storage at the temperature 5 °C, the highest value -3323.77 $g.s^{-1}$ was found in the sample C after 10 days of storage at the temperature 5 °C. The value of the viscosity in each of the samples didn´t change much, not even after the ketchups were stored at a room temperature for 24 hours (Fig. 3).

The viscosity of each of the ketchups from the second batch determined by the regressive extrusion ranged form -1586.04 $g.s^{-1}$ to -3294.74 $g.s^{-1}$. The lowest value -1 586.04 $g.s^{-1}$ was found in the sample A after 10 days of storage at the temperature 5 °C, the highest value -3294.74 $g.s^{-1}$ was found in the sample C after buying in a market and consequential cooling to 5 °C. The value of the viscosity in each of the samples didn´t change much, not even after the ketchups were stored at a room temperature for 24 hours (Fig. 4).

The viscosity of ketchup is highly influenced by the approach in production. The production of ketchup uses a so-called „hot break" process. It means that the tomatoes are very quickly warmed up to at least 77 °C but usually 90 °C. At this temperature enzymes begin to sunder which preserves a higher pectin level. It means that by destroying all the enzymes using a „hot break" process a more viscous product is made, less susceptible to separation **(Pritchard & Burch, 2003)**.

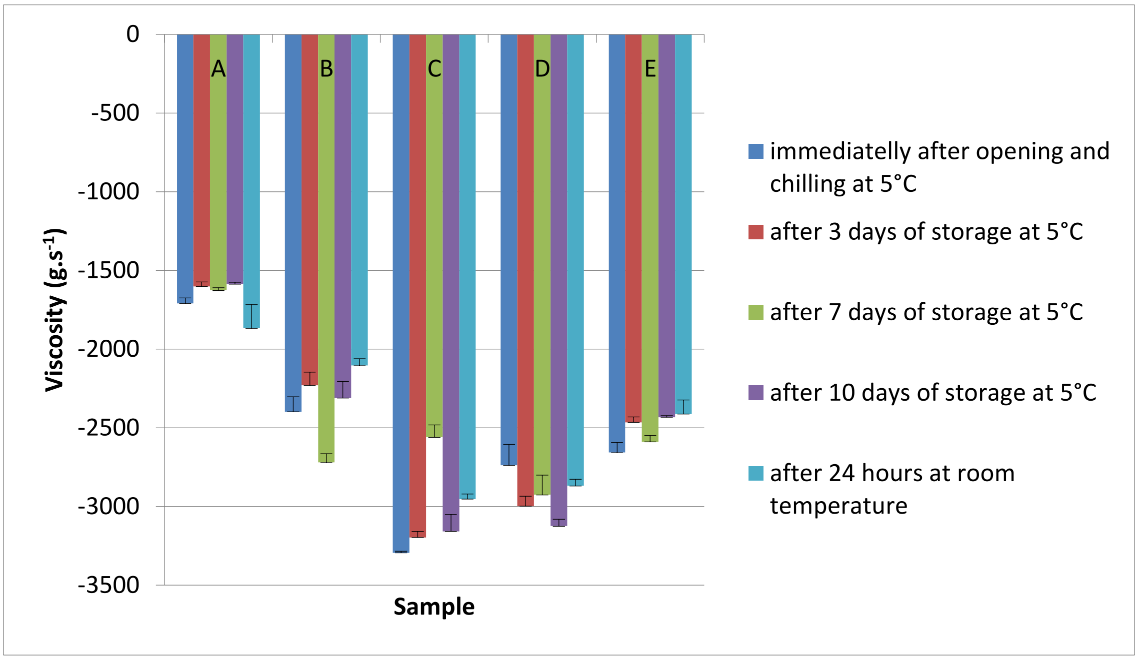

Figure 5 The average values of viscosity for each of ketchup A-E of the second batch depending on storage

The graph shows the average viscosity of ketchup of the second batch (sample A – E), depending on storage, where fault segments with standard deviation is shown.

Table 3 Statistical comparison of the viscosity of the first and second batch of ketchup A-E

Storage conditions	***p* - value**
Immediately after opening and chilling 5 °C	0.003722
After 3 days of storage at 5 °C	0.005399
After 7 days of storage at 5 °C	0.005167
After 10 days of storage at 5 °C	0.001790
After 24 hours at room temperature	0.001535

The viscosity is the ketchup most important property, which is invariable, thanks to the fact that the ketchup homogenises during the production process, the viscosity of ketchup is preserved even after expiry of a period of time during storage. Ketchup that is adequately viscous gives a better taste in your mouth and it seems denser, which has the effect that the ketchup remains longer in the mouth and releases its flavour more slowly **(Race, 1991)**.

After applying a nonparametric statistical method Kruskal-Wallis 1-Way ANOVA 1 to compare the consistency of the first and second rate of ketchups A-E, it´s safe to say that there´s a highly significant statistical difference between them at different storage conditions, where $p < 0.01$. Statistical comparison of the consistency of the first and second batch of ketchup A-E is on Tab. 2. Statistical comparison of the viscosity of the first and second batch of ketchup A-E is on Tab. 3.

Ketchup A from the first and the second batch had the lowest consistency value, which could be caused by sucralose, which was used as a sweetener instead of glucose. The ketchup C from the first and the second batch had the highest consistency value. The ketchup D achieved also quite high consistency value but during its production there were no thickenings or additives used. All the other ketchups contain a modified starch E 1422, which adjusts the consistency.

CONCLUSION

The samples of ketchups A-E originating from common supermarkets. The samples were different kinds of ketchup such as soft, hot and sweet. They also had different structures and wrappings. The properties like consistency and viscosity were monitored right after bought and cooled to 5 °C. Further measurements were carried out after 3 days, 7 days and 10 days always at a temperature of 5 °C. Finally, we left the samples at a room temperature for 24 hours and consecutively measured them. From the PC programe *Exponent* we chose a methodology for measuring ketchups, we used regressive extrusion method using a probe and a hyperbaric disc. It arises from the viscosity and consistency values of the measurements that there´s a highly statistically important difference between the first and the second rate.

Based on the results of the texturometric measurements of the properties of ketchup and their consecutive statistical evaluation, our recommendations are following:

- Choose wisely the appropriate method „hot break“ or „cold break“, which directly influences the texture properties of the product.
- Use quality raw materials while producing. These influent the qualitative properties of the ketchup highly.
- Use a right amount of additives which influent mostly the consistency but also the durability of the product
- Follow the required conditions while storage as they are presented on the wrapping of the product.

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