Textural and Flavour Characteristics of Commercial Tomato Ketchups

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Abstract

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A set of 20 samples of tomato ketchup purchased on the market were analysed by several rheological procedures (RheoStress 300) and by sensory profiling of both textural and flavour characteristics. A great variance was observed of all characteristics in all sample variables. About a third of plots between two variables were significantly related in the case of two rheological attributes and two sensory attributes, and in that of combinations between rheological and a sensory attributes. Similarly as in the case of lipid dispersions, the sensory texture acceptability was significantly related to the overall flavour acceptability. This proves the importance of texture in the consumption of tomato ketchup.

Keywords: tomato ketchup; rheology; sensory characteristics

The flavouring ketchup is derived from the name "kechap", originated in the Far East, which means "a spicy fish sauce". Therefore even now the ketchup produced in Asian countries may contain ingredients such as surimi (Niwa *et al.* 1990) or oysters (Heu *et al.* 2006). In the 18th century, the product was imported to Europe, and now, ketchup is almost exclusively prepared from tomato juice, onion, vinegar, sugar, and various spices (Brummer 2006).

Consumers prefer thick products, therefore, tomato ketchup is now prepared with the addition of thickeners (Varela *et al.* 2003), e.g. tomato pulp powder (Farahnaky *et al.* 2008), starches – potato or corn starches (Bonnefin 2000), modified starches (Lee *et al.* 1997), various hydrocolloids, e.g. carboxymethylcellulose, xanthan gum, locust been gum, guar gum, and traganth gum are now increasingly used (Sahin & Ozdemir 2004).

The intensive application of thickeners results in a great number of products with variable rheological properties. Therefore it would be useful to investigate the relationships of texture in a larger set of commercial samples. The samples should be tested from the standpoint of psychorheology

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(Barnes 1999), i.e. the combination of rheological and sensory properties.

MATERIALS AND METHODS

A total of 20 commercial samples of tomato ketchup were purchased at various supermarkets and immediately stored in a refrigerator. Some samples were of local production, but most of them were imported. The samples were then analysed both at 23°C and 45°C (a total of 40 results). The temperature of 23°C corresponded to the room temperature, the temperature of 45°C corresponded to ketchup applied on to hot meal.

Rheological analysis. Several rheological data were obtained (Table 1). The flow curves, apparent viscosity, thixotropy, storage elasticity modulus, loss viscosity modulus, and the complex modulus were measured using a rheometer RheoStress 300 (Thermo Haake, Karlsruhe, Germany) the determinations were carried out in coaxial cylinders, equipped to prevent slipping on the walls of measuring cylinders. The statistic yield stress was determined using a vane rotor (Steffe 1996) as the maximum value of the shear stress on the time axis at a constant shear rate at the vane rotor $\gamma = 0.5\ s^{-1}$.

It was found that, from the rheological point of view, ketchup is a viscoplastic substance. The results agree with the Herschel-Bulkley equation (Roberts 2003; Jaros & Rohm 2003):

$\tau = \tau_o + \eta_{pl} \times \gamma^n$ (later only H-B)

Table1. Descriptors of the rheological characteristics

Rheological characteristics	Symbol	Physical unit
Apparent viscosity	η_a	Pa.s
Plastic viscosity (H-B)	η_{pl}	Pa.s
Flow exponent (H-B)	N	–
Thixotropy	Th	Pa/s
Static yield stress	τ_o	Pa
Loss viscosity modulus	G''	Pa
Storage elastic modulus	G'	Pa
Complex elasticity modulus	G*	Pa

H-B – derived from the Herschel-Bulkley equation

A good agreement between the experimental results and the Herschel-Bulkley equation was reported also from another source (Varela *et al*. 2003).

The time dependent flow behaviour of ketchup is generally known. To be removed from the bottle, it needs first to be shaken vigorously for a few seconds. In order to prove thixotropy, the bottle should be left undisturbed for a while. Thixotropy was determined by measuring the area of hysteresis (the area between up and down flow curves).

The existence of thixotropy (Th) of tomato ketchup is evident from Figure 1, constructed according to the dynamic test given by Brummer (2006).

The structural breakdown and subsequent building of the structure is explained here. The first part of the experiment was performed in a linear viscoelastic range. In the second part the strain increased sharply. This behaviour results in a significant decrease of all moduli. In the third part of the experiment, the strain decreased suddenly, returning again to the original viscoelastic range, and after a few minutes both the moduli reached again their starting values. Earlier, the thixotropy of tomato ketchup was reported from another laboratory (Autio & Houška 1991; Metzger 2006).

Sensory evaluation. The sensory analysis was carried out in a standard sensory laboratory provided with 6 testing booths (ISO 8589: 2007). The analysts were selected, trained, and monitored after (ISO 8586-1: 1993) and had possessed practical experience for six months; sensory profiling was included. The samples were served on white porcelain dishes. Maximum of three samples were tested at the same session. The same analyst evaluated the same samples twice, the samples having been served in random order at different sessions. The judges (9 women and 3 men) were served samples which were prepared and served according to the international standard (ISO 6658: 2005). They were presented 25 ml ketchup in 50 ml glass beakers, marked with 4-digit codes. The flavour acceptance was also determined by testing 10 g ketchup on 50 g French fries. Tap water and white rolls were taken in between the samples. The scales used consisted of unstructured straight lines 160 mm long (converted to %), oriented by descriptors at both ends (ISO 4121: 1987). The list of descriptors is given in Table 2. The flavour acceptability was also determined (ISO 6564, 1985) in an experiment in which 10 g ketchup were consumed on 50 g of French fries.

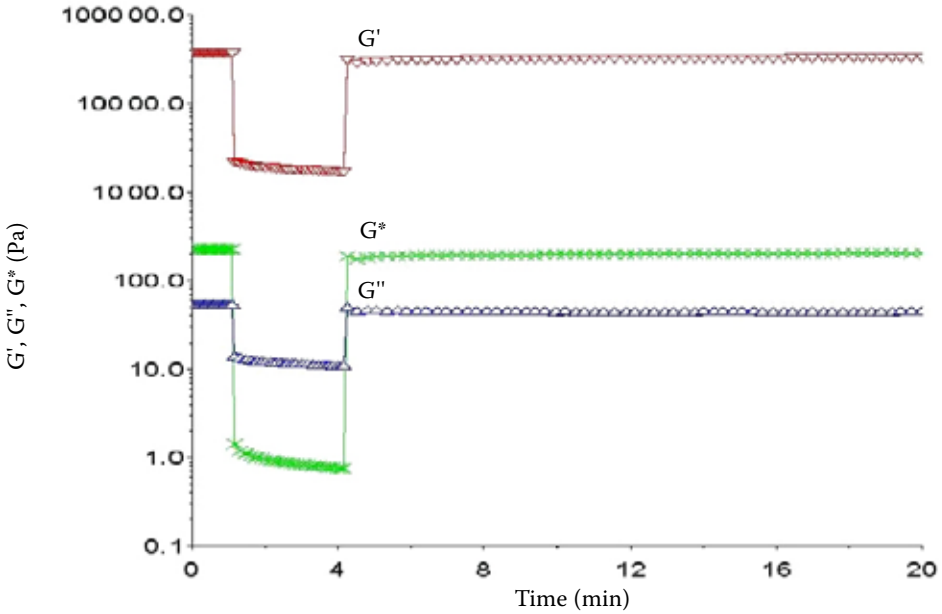

Figure 1. Breakdown and building of the tomato ketchup structure under strain

The bottles with ketchup were kept upright down for 2 h and the amounts of ketchup remaining in the bottles were weighed.

Statistical methods. The data obtained in the experiments were analysed by ANOVA and multiple regressions using the software STATISTICA 4.0.

RESULTS AND DISCUSSION

It could be expected that the properties of ketchups would be very variable depending on the manufacturers' plans. The data given in Table 3 confirm the expectation, thus more detailed study is useful.

Standard deviation varied by 30–40% of the respective means, while the values varied between 15–20% in the case of sensory evaluation.

In spite of the great variability in the properties, the number of significant relationships (P = 0.05) was surprisingly high (out of 141 variables combinations, 58 were statistically significant, 15 relationships were significant even on the probability level of 0.005). Most relations were linear or very close to linearity, which may be explained by a narrow range of values in the material tested. No relationship was detected between the static yield stress and other variables.

As could be expected, many relationships were found among rheological variables, e.g. between

Table 2. Descriptors and the limits of unstructured graphical scale

Sensory attribute	Left end	Right end
Colour hue	red	brown
Resistance, to taking and stirring and ladling with a spoon	very easy	difficult
Resistance, to pouring from the spoon	very easy	difficult
Viscosity observed at ingesting the sample	very small	very thick
Viscosity observed on pressing the sample against the palate	very small	rather thick
Sensory texture acceptability	bad	excellent
Intensity of spicing	weak	very strong
Overall flavour acceptability	bad	very good
Hot taste after swallowing	weak	very strong
Taste on French fries	bad	very good

Table 3. Variability of individual characteristics

Characteristic	Mean	Minimum	Maximum	Standard deviation
Apparent viscosity (Pa.s)	0.77	0.17	1.42	0.25
Plastic viscosity (H-B) (Pa.s)	13.6	0.40	33.4	7.2
Flow exponent n (H-B) (–)	0.68	0.20	1.6	0.42
Thixotropy (Pa/s)	522	0.05	2700	534
Static yield stress (Pa)	45	25	65	11
Loss modulus (1 Hz) [Pa]	287	120	675	125
Storage elastic modulus (1Hz)	66	30	140	33
Loss modulus (10 Hz) (Pa)	433	220	950	185
Storage elastic modulus (10 Hz) (Pa)	137	55	300	72
Crosspoint of moduli (%)	53	10	75	17
Residue in the bottle after pouring out ketchup (g)	10	2.3	19	3.9
Colour hue (%)	42	23	62	12
Resistance of ketchups on ladling with a spoon and stirring	35	23	47	62
Resistance to stirring (%)	35	23	47	6.2
Resistance to pouring out (%)	54	30	74	10
Viscosity after ingestion (%)	48	27	70	11
Resistance to pressing against palate (%)	44	26	66	9.4
Sensory texture acceptability (%)	56	35	69	7.8
Intensity of spicing (%)	60	42	77	9.9
Flavour acceptability (%)	47	16	67	12
Hot taste after swallowing (%)	53	36	80	13
Flavour of ketchup on French fries (%)	64	22	68	13

thixotropy or storage modulus and the residues after pouring the samples out of bottle. An interesting example is the significant relationship between the plastic viscosity (HB) and the apparent viscosities (Figure 2).

The relationships between two sensory characteristics are very interesting, especially in the sensory testing on the palate (i. e. before the sample ingestion, before the sample is heated and mixed with saliva), as well as between the resistance to ladling (including mixing) and to pouring out the sample from a spoon (Figure 3). The pouring of the sample out of a spoon is, in its turn, linearly correlated with the perception of sensory viscosity, measured immediately after ingesting the sample in the mouth; the sample is not heated and mixed with saliva at this stage. The pouring is in a significant relation with the overall flavour, which shows the importance of the texture for the acceptability of ketchup by the consumer. A close relationship was observed between the spicy perception immediately after the ingestion and the hot taste after swallowing. In some cases the rheological measurement could predict a particular sensory attribute, e.g. the relation between the storage modulus G' and the resistance of the sample to pouring from a spoon (Figure 4). Another example is the significant relationship between the storage modulus G' and the viscosity perceived in the mouth immediately after the sample ingestion (Figure 5).

Surprising is the close correlation between the sensory texture acceptability, and overall flavour acceptability (Figure 6). Similar relations were observed in fat foams (Štern *et al.* 1988), mar-

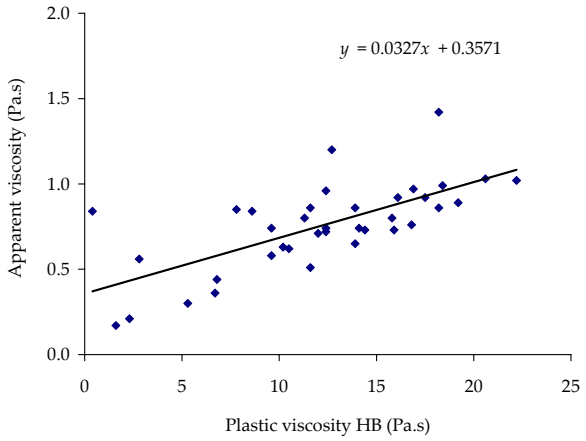

Figure 2. Relationship between the plastic viscosity (H-B) and the apparent viscosity

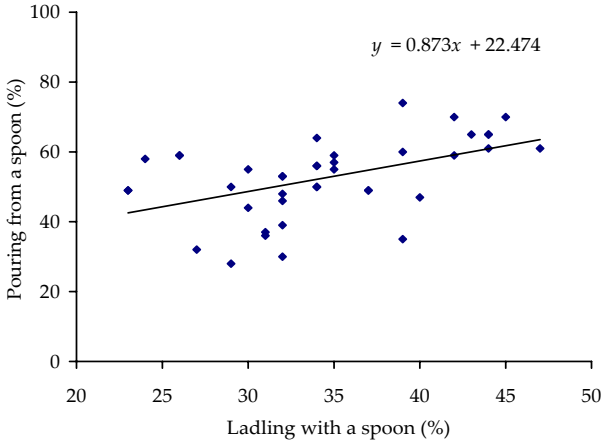

Figure 3. Resistance of ketchups to ladling with a spoon and pouring out of the spoon

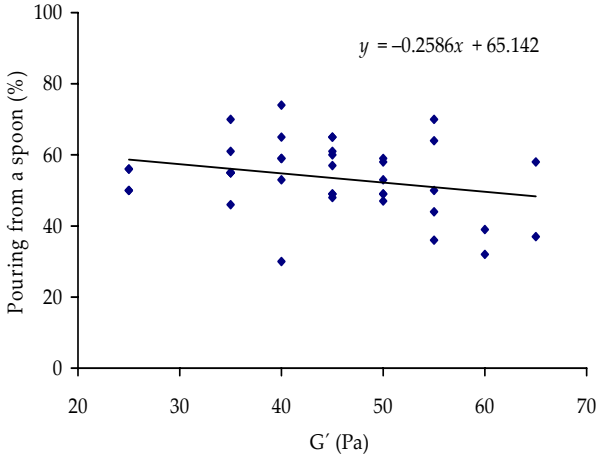

Figure 4. Relationship between the storage modulus and the resistance against pouring the sample from a spoon

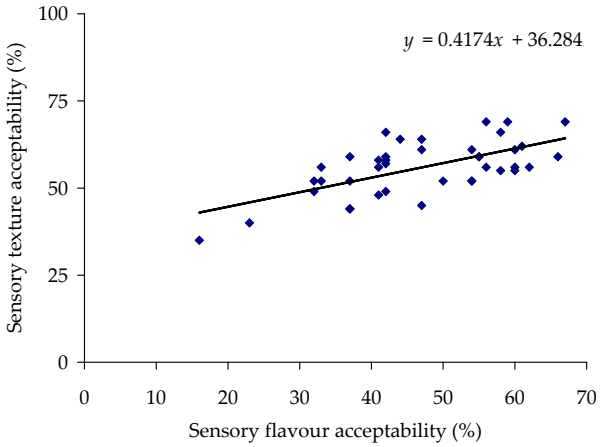

Figure 5. Relationship between the storage modulus and the viscosity in the mouth after ingestion

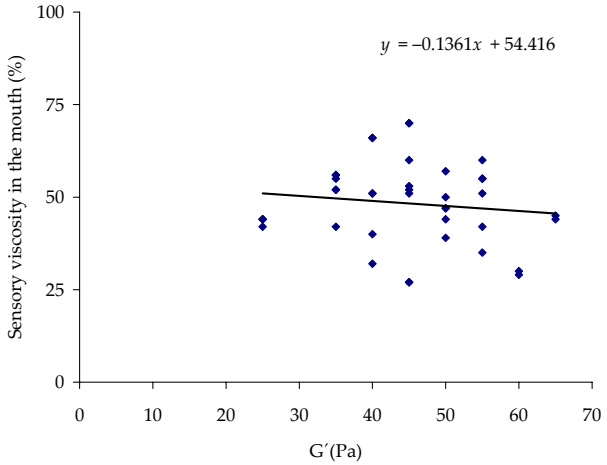

Figure 6. Relationship between the sensory texture acceptability and overall flavour acceptability

garines with varying fat content (Štern *et al.* 2001), yoghurt mayonnaise (Štern *et al.* 2008) or tartar sauce (Štern *et al.* 2006). The data prove the importance of the texture perception for the overall flavour evaluation.

CONCLUSIONS

A set of 20 commercial ketchups were tested at two temperatures using several rheological methods and sensory profiling. Great differences were observed between the samples, however, many statistically significant relationships were found in statistical evaluation, partially also between the rheological and sensory characteristics. Similarly

as in the case of lipid dispersions, a close relation was observed between the sensory texture acceptability and overall flavour acceptability.

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