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SENSORY ANALYSIS IN FOOD RESEARCH, QUALITY ASSURANCE AND PRODUCT DEVELOPMENT

A review

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The review shows recent development of sensory analysis interfaced with the measurements of consumer preferences and its unique position among food analysis methods. Possibilities of application of sensory methods in the area of food science, product development and food quality assurance are discussed on three examples (case studies) taken from the authors own research.

Keywords: sensory analysis, tastant mixtures perception, bread flavour, sensory quality assurance

Food quality is a complex phenomenon, comprising safety, nutritive and sensory aspects. Sensory perception is recognised as the most important determinant in food choice behaviour (TUORILA & PANGBORN, 1988a,b) and subsequent food intake, with its all consequences for consumer health and psychological satisfaction. Therefore sensory quality of food is of interest for food scientists, nutritionists as well as for food producers and marketing researchers.

Among analytical methods applied in evaluation of food quality, sensory methods occupy a unique position. Whereas physical, chemical or microbiological methods deliver information about respective properties of the foodstuff itself, sensory methods inform about how the above properties are perceived by human senses. In other words, by instrumental analysis we might be informed about sensory stimuli in food – but not about sensory quality which, by definition, is human sensory response to those stimuli and cannot be considered separately from the human sensory apparatus. An implication of the above mentioned is that sensory analysis is complementary to physical, chemical or microbiological analysis in describing overall food quality – but it cannot be replaced by them.

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Historically, sensory analysis is a relatively young branch of food analysis: first sensory methods (discrimination tests, scoring systems) have been developed and applied in the food and beverage industries in the late forties and early fifties (PLANK, 1948; BOGGS & HANSON, 1949; SJÖSTROM, 1951; TILGNER, 1954).

Poland had its remarkable contribution in the early development of sensory analysis. It was due to the pioneering scientific research of professor Damazy Tilgner. His book on organoleptic (sensory) analysis of food (TILGNER, 1957) is internationally recognised as the first text book on this topic.

Since that time sensory methodology and the area of industrial and scientific application of sensory analysis extended greatly. Today sensory analysis together with consumer research is a powerful and widely applied analytical tool to successful marketing of foods in the strong competitive environment (STAMPANONI, 1994; SHEWFELT et al., 1997).

Parallel with industrial application, sensory methods became widely used in food science for studying the effects of raw material and processing, storage and packaging on sensory quality in the "real" products as well as in model systems. The development of basic research on physiology, psychophysics and psychology of human sensory perception and cognitive processes contributed substantially to understand better sensory phenomena and to build sound basis for methodological development in sensory analysis.

Below three examples taken from the authors' own research will illustrate diverse area of its application.

1. Sensory interaction of complex taste/texture stimuli

In sensory perception of food products, integrated sensory responses to the product composition and changes due to processing alternation or ingredient substitution are observed. In consumer dimension, if resulting sensory quality does not meet consumer expectation, the preference rating gets lower or the product is not accepted at all. Collected results concern and are valid for the given experiment(s), but give little contribution to elucidate general rules and behaviour of mixed stimuli and related sensory responses, so they have limited predictive value for the final sensory effect in foods (LAWLESS, 1986). Thus, model studies directed to discover general and consistent stimuli/responses relationships are of great importance, as effective and informative, also for practical application of sensory science in food manufacture and new product development.

Publications on sensory perception of complex taste stimuli and interaction phenomena have concerned simple binary mixtures of tastants in water or drinks (MCBRIDE & JOHNSON, 1987; MCBRIDE, 1989; FRANK et al.; 1993, SCHIFFERSTEIN, 1994).

Very little is known about the interaction of the stimuli in cross-modality mixtures (e.g. odour-taste or texture-taste). Suppression effect of texture-modifying hydrocolloids on the intensity of sweet and acid tastes evoked by single stimuli (sucrose, citric acid) was observed in the early study by PANGBORN and co-workers (1973). The viscosity of hydrocolloid, and even more its chemical structure affected the degree of suppression of sucrose and aspartame sweetness (MÄLKKI et al., 1993; CHAI et al., 1991). All the above observations concerned single taste stimuli; none of the mentioned authors studied the perception of mixed taste stimuli in hydrocolloid environment.

In our study (BARYLKO-PIKIELNA et al., 1999), the effect of two hydrocolloidal model systems (4% gelatin gel and 1% agar gel of the same hardness measured instrumentally) on the perception of sweet and acid taste in mixtures was tested. Sweet taste was represented by sucrose (SUC) (0–0.58 mol l^{-1}, 0–20%) and aspartame (ASP) (0–0.013 mol l^{-1}, 0–0.375%), acid taste by citric acid (CA) (0–0.014 mol l^{-1}, 0–0.3%). In each gel five concentrations of sucrose and four concentrations of citric acid were factorially combined and evaluated for intensity of sweetness and acidity. The set of 20 samples was randomly divided into two sub-groups and evaluated by a 10-member trained panel in two replicates. The results (on the example of SUC/CA mixtures) are displayed on the Figs 1–4.

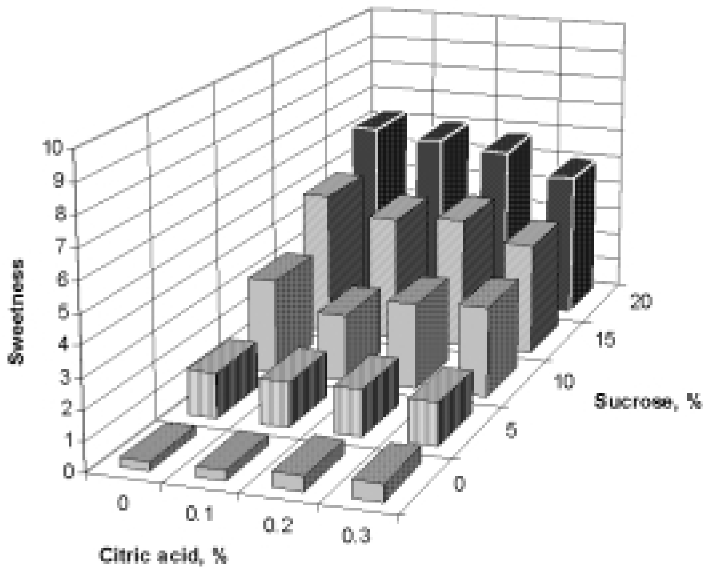

Fig. 1. Factorial plot of the sweetness of sucrose/citric acid mixture in agar gel (BARYLKO-PIKIELNA et al., 1999)

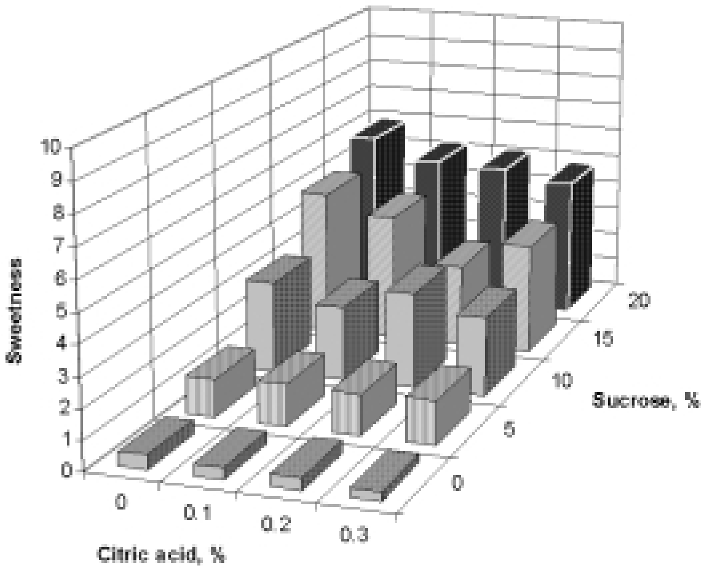

Fig. 2. Factorial plot of the sweetness of sucrose/citric acid mixture in gelatine gel (BARYLKO-PIKIELNA et al., 1999)

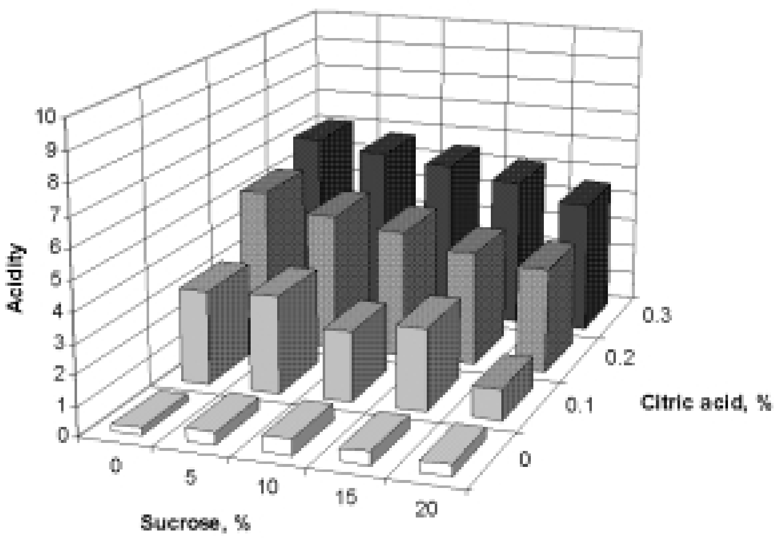

Fig. 3. Factorial plot of the acidity of sucrose/citric acid mixture in agar gel (BARYLKO-PIKIELNA et al., 1999)

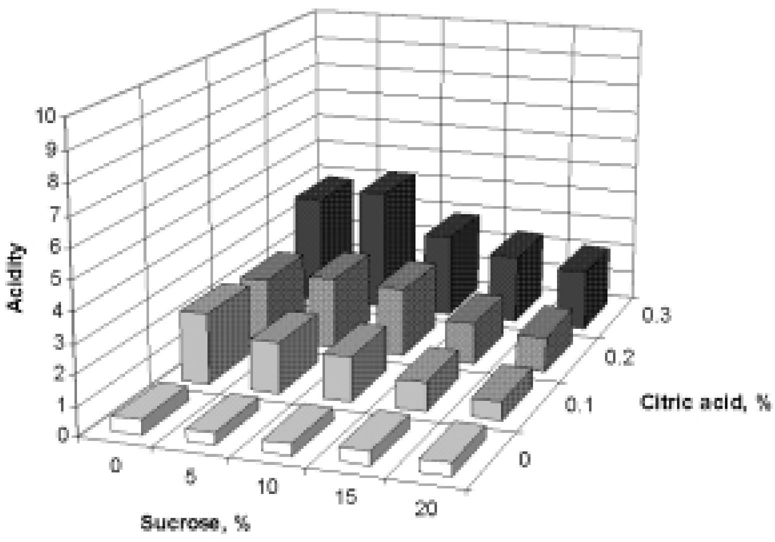

Fig. 4. Factorial plot of the acidity of sucrose/citric acid mixture in gelatine gel (BARYLKO-PIKIELNA et al., 1999)

In sweet/acid tastants mixture in both gels (agar and gelatine) sweetness and acidity showed generally the same behaviour as the same tastants mixture in water solution with the suppression as main effect (MCBRIDE, 1989). The mutual suppression of both tastes in the mixture was unbalanced: suppressive effect of sweetness by acid taste was slight and insignificant in both gels (Figs 1 and 2). Contrary, suppression of acidity by sweet taste was strong and highly significant (Figs 3 and 4). What's more, the kind of gel matrix affected the intensity of acid taste but not that of sweetness. Perceived acid intensity in agar gel was about 50% higher than in gelatine gel; the intensity of sweet taste was the same in both. Thus, the sweet/acid balance in each hydrocolloid was different. In ASP/CA mixtures all the above effects and relationships were the same.

The above results illustrate the complexity of mixed stimuli systems and related psychophysical phenomena, even when investigated in controlled, relatively simple model mixtures of only 2 taste stimuli in pure protein or polysaccharide colloidal environment. On the other hand, they show that from psychophysical point the rules and relationships, common to complex taste perception caused by mixed stimuli, are valid in spite of different medium. They can be successfully interpreted by applying an approach suggested by integration psychophysics (MCBRIDE & ANDERSON, 1990). Model experiments, as these in the study, may provide experimental data of predictive value under the condition that stimuli concentration will mimic the range and the ratio to each other found in "real" food (BONNANS & NOBLE, 1993).

In practice they may provide a tool for food manufacturers to predict final sensory effect in new product development to get sensory properties of the product tailored to the needs and expectations of consumers.

2. Time-intensity (T-I) characteristics of bread: the effect of salt

It is known that salt is an important taste component in bread (SALOVAARA et al., 1982) and consumers tend to accept low-salt breads (recommended for health reasons) less readily than normal-salt breads (TUORILA-OLLIKAINEN et al., 1986). So far, interrelations between saltiness and other sensory characteristics in bread have been very little studied. The perception of flavour in bread is a particularly time dependent phenomenon. Bread, like other solid foods, requires sequential manipulation with the tongue and mastication to break down the solids and mix them with saliva for swallowing (KELLING & HALPERN, 1983). Flavour release is a result of the above phenomena. Therefore, a study of the time-intensity dependence of the main sensory characteristics of bread was undertaken to help understand their possible interrelations and their contribution to consumer acceptance of bread with different (including low) salt concentrations. The aim of the study was to determine time dependent variations in the intensity of sensory characteristics (saltiness, sourness and overall flavour) of wheat and sour rye breads with different salt concentrations (BARYLKO-PIKIELNA et al., 1990).

Nine samples of both bread types containing different amounts of salt, were baked in a pilot-plant bakery, frozen in polyethylene bags and kept in a freezer until the day before analysis by T-I method.

The four-member panel evaluated all samples (in duplicate). A computerized procedure was used to measure time-intensity (T-I) of saltiness, sourness (only in rye bread samples) and overall flavour.

The scale was anchored at both ends: none – very intensive. The signal was recorded by the computer every 0.1 s, tracing temporal changes in the intensity of the attribute being evaluated. Individual and time-averaged results were obtained from the T-I data, giving the following information: (1) lag time (s), (2) time to reach maximum intensity (s), (3) total duration (s), (4) maximum intensity (100-point scale) and (5) area under the curve (integral).

As it was stated, in wheat bread the time-averaged T-I response curves for saltiness (Fig. 5a) and overall flavour (Fig. 5b) rose and the duration of taste sensation became longer with an increase in the concentration of NaCl in the samples. The curves for an overall intensity of flavour closely resembled the curves for saltiness. This might be an indication of the importance of saltiness to the overall flavour of wheat bread. Wheat bread with a very low salt concentration had only very weak flavour.

The observations were confirmed by statistical analysis of the numerical data from the curves (ANOVA, Tukey test). Maximum intensity, total duration and the integral showed a regular rise with increasing NaCl contents. Statistical significance of differences was only found at the extremes, i.e. between the lowest and the highest concentration (BARYLKO-PIKIELNA et al., 1990).

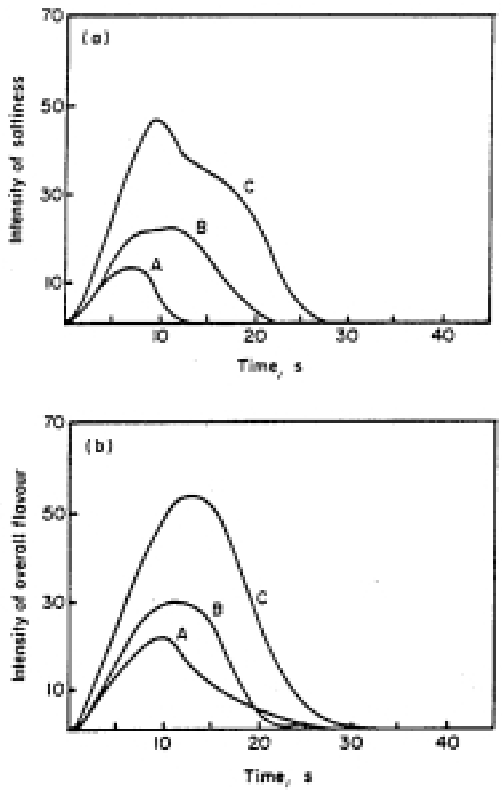

Fig. 5. Average time intensity response curves (n = 8) for a) saltiness and b) overall flavour of wheat breads, A = 0.25%, B = 0.63%, C = 1.06% NaCl (BARYLKO-PIKIELNA et al., 1990)

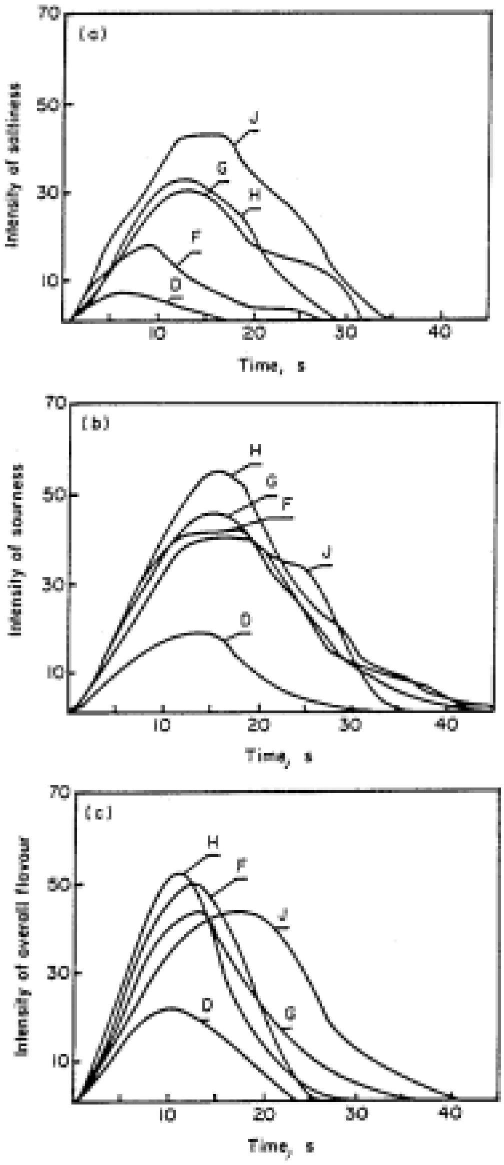

Fig. 6. Average time intensity response curves (n = 8) for (a) saltiness, (b) sourness and (c) overall flavour of rye breads, D = 0.26%, F = 0.75%, G = 0.98%, H = 1.35%, J = 1.55% NaCl (BARYLKO-PIKIELNA et al., 1990)

The T-I curves for the saltiness of rye bread (Fig. 6a) rose gradually with the increase in the salt concentrations as in wheat bread. However, the increase was not regular: the curves for samples with 0.98% and 1.35% NaCl content were almost identical. The curves for sourness were quite different from those for saltiness (Fig. 6b): the rise in salt concentration from 0.25% to 0.75% resulted in significant changes in the T-I curves for sourness, in both maximum intensity and total duration, whereas a further increase in the NaCl concentration had only a slight effect on sourness. The curves for overall flavour (Fig. 6c) were similar to those for sourness in rye bread. NaCl content of at least 0.75% in rye bread seemed to be critical for the development of full flavour. Further NaCl elevation caused only minor increase in flavour. The highest salt concentration (1.55%) resulted in an increase in the duration of overall flavour but not in an increase of its maximum. When the salt level in rye bread rose, saltiness and sourness competed with each other and had a kind of synergic effect by NaCl concentration within the range of 0.75–1.35%.

At all salt concentrations, except for wheat bread, the curves of overall flavour corresponded well with those of sourness, but not with saltiness – except at the highest concentration (1.55%), where saltiness seemed to dominate over sourness.

These findings suggested that at least in sour rye bread it is possible to lower the commonly used 1.5% NaCl concentration even to 0.75% level without negative changes in flavour fullness and its acceptance – thus lowering considerably the daily salt intake, recommended for health reasons.

3. The SQCCP – a new concept of sensory quality assurance

The above two examples illustrate the possibility of application of some sensory methods as analytical tools to solve certain question of basic or applied character – and kind of information derived. However, when the problem to be solved is more complex – as it is in the case of quality assurance of food – the tools shall be put together within the effective system capable to ensure favourable and prevent unfavourable quality changes. This example concerns application of sensory methods within such a system.

To consumers the most important aspect of food quality is undoubtedly the sensory experience imparted during consumption. The appearance, texture, flavour/aroma and especially taste, together with convenience of use and price are the decisive factors in food choice, brand choice and subsequent consumption with all nutritional consequences. Therefore it is logical that it should be ensured with the similar care, as the safety is ensured by HACCP, in an analogue preventive manner.

This assumption was made in the beginning of the development of Sensory Quality Critical Control Point methodology, which was an objective of a joint project within the EC Copernicus programme, realised by three research institutes and one industrial partner from United Kingdom, Hungary and Poland (MACFIE et al., 1996; BARYLKO-PIKIELNA et al., 1997a).

The difficulty in the development of SQCCP system as compared with known HACCP one comes from two sources. First, the target to be reached – high and consistent sensory quality of the product in question – is product-specific and shall be considered for each type of food and each foods group separately. Low microbial or chemical contamination are common criteria of safety for all foods – common sensory criteria do not exist.

Secondly, the target – sensory quality of food – is much more complex than safety measures. There are many elements required to define sensory profile of the product and profile itself is a far more multivariate phenomenon than microbiological count or level of the given chemical contaminant.

In spite of the above constrains, the outline of the SQCCP system was developed and basic of required procedures and methodologies were elaborated and checked in the pilot plant or full industrial scale. Although working on the example of specific product (soft margarine), it was kept in mind that the system shall have more general dimension.

The developed system consists of several elements (or steps) to be sequentially handled:

Step 1 – Determining optimum (target) sensory profile of the product on carefully defined criteria (the main criterion: high consumer hedonic value),

Step 2 – Determining sensory attributes of key importance for consumer degree of liking,

Step 3 – Identifying Critical Points (in raw materials, additives, processing) potentially affecting sensory quality of the finished product,

Step 4 – Determining qualitative and quantitative effects of raw materials and other ingredients on the sensory quality and product acceptance for identification of actual CCP,

Step 5 – Monitoring day-to-day variation in product sensory quality against target sensory profile and parallel monitoring of variation in formulation and processing factors. Confirming the actual CCPs and limiting variation at these points to meet target quality.

The target – optimum sensory profile. Precise definition of target sensory profile to be reached is of fundamental importance. Therefore special attention was given to this first step of the system. Analysis by preference mapping (GREENHOFF & MACFIE, 1994), together with parallel sensory profiling appeared to be an effective technique for the above purposes. To determine consumer-oriented optimum sensory profile, consumer degree of liking of low- and full-fat soft margarines and mixed spreads (leading products on Polish food market) were tested in unlabelled condition, in two consecutive years, each time by a hundred people consumer group (housewives), varying in age, education level and living place. The same products were analysed by a trained panel using QDA (profiling) method. Preference mapping of product loading plots of the evaluated spreads and panel means attribute superimposed on it (PCA projection) allowed to find out which attributes are mainly responsible for consumer preferences decisions. Natural butter-like odour and flavour (in positive way) and hydrogenated fat odour and flavour (in negative way) appear to be of primary importance (Fig. 7). Colour, oily flavour and sweet, acid and salty taste showed considerable variability too, however, their influence on overall sensory quality and consumer preferences was of secondary importance (BARYLKO-PIKIELNA et al., 1997a,b).

The analysis resulted in defining "target profile" of the margarine in qualitative and semi-quantitative way.

Attributes of key importance. Practical implementation of SQCCP in the industrial environment requires simplification of the methodology, focusing on the attributes which are critical for the overall quality and consumer liking of the product. Variability of an attribute and its possibly close relationship with consumer hedonic rating were applied as selective criteria. Graphical visualisation of such relationship appeared to be very helpful for preliminary inspection of its strength, shape and eventual clustering (Fig. 8). Followed by calculation of correlation coefficients they were an effective approach for selection of key attributes of the product.

Potential critical points in product formulation and processing. When optimal profile of the product was defined, identification of potential Critical Points related to the chosen attributes of key importance in product raw material(s), ingredients, additives and processing parameters was done by careful inspection and analysis of the whole manufacturing process from the point of potential effects on sensory quality.

In the case of soft margarine processing, qualitative inconsistency of functional ingredients and additives and their periodical preparation before entering them into main continuous processing appeared to be potentially critical. They may result in variation of sensory quality of the finished product.

Qualitative and quantitative changes in product formulation and their effects on its sensory quality. Checking the effects of wider variation in a quality of raw material, ingredients and additives of the spread on its sensory quality was conducted in pilot plant experiment. Full-scale experiments were hardly possible, because of limited manipulation range and inert response to the processing parameters change (due to the large volume of installation).

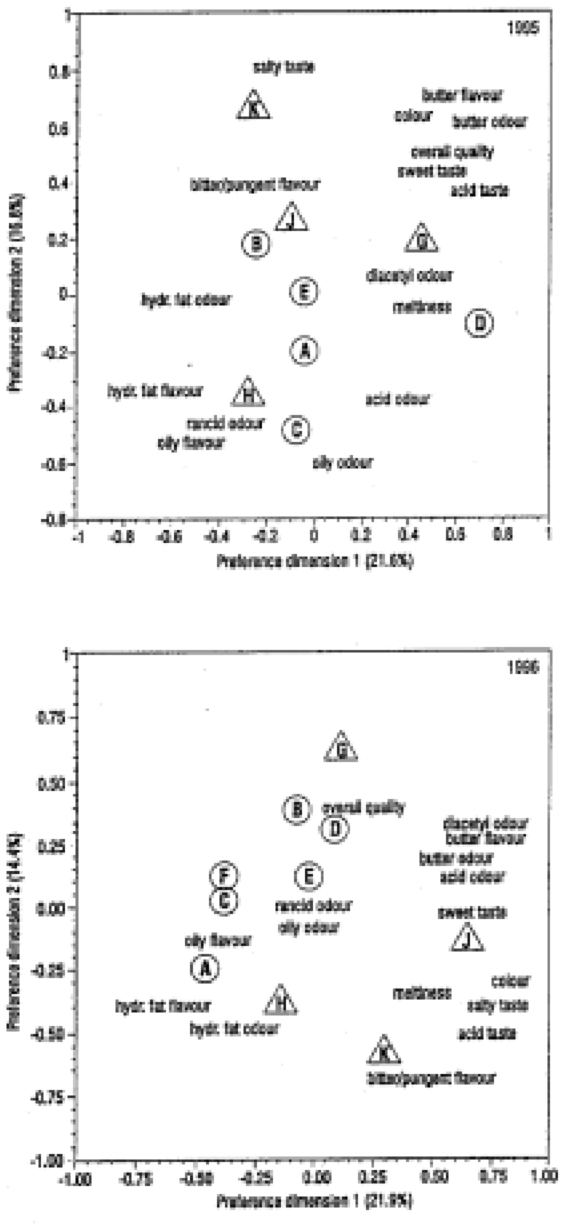

Fig. 7. Comparison of preference map product loadings plots of low-fat (O) and full-fat (Δ) margarines and mixed spreads showing correlations with sensory panel attribute means (BARYLKO-PIKIELNA et al., 1997b)

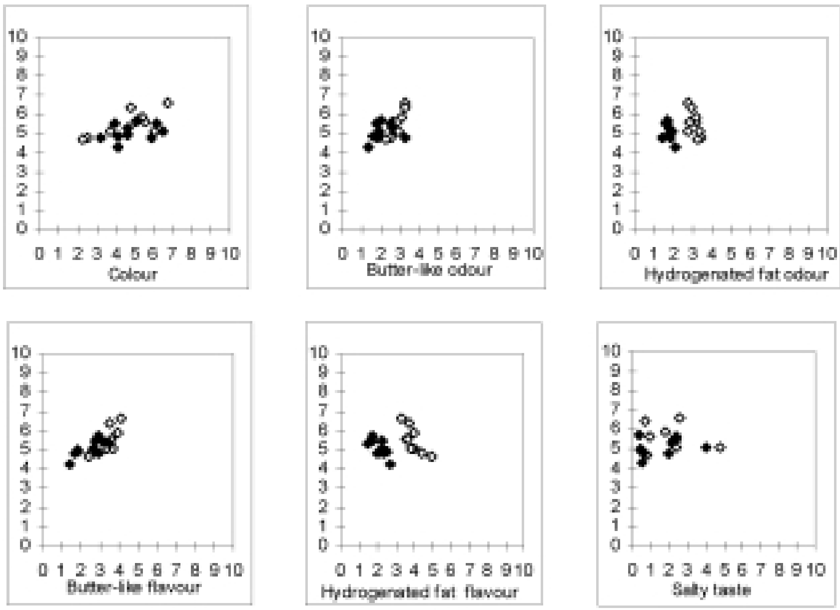

Fig. 8. The plot of relation between attributes intensity /horizontal/ and consumer degree of liking /vertical/ of evaluated margarines and mixed spreads – selected examples. ◊: Year 1995; ♦: year 1996 (BARYLKO-PIKIELNA et al., 1997a)

The performed factorial experiment in pilot plant scale had shown, that in the product like fat spread, the quality of added flavouring (highest ingredient effect – Table 1) was critical for the quality of finished product and its hedonic value.

Day-to-day process monitoring. Valuable source of information about the relation (or its lack) between chemical or physical characteristics of the product component(s) and sensory effect in finished product was a systematic observation of the variation in sensory attribute and related instrumental measurement. In Fig. 9 one can see that there was no relationship between softening point of esterified fat or margarine and its sensory meltiness – although it is used as an indicator of the latter (BARYLKO-PIKIELNA et al., 1997a).

Methodological aspects. Development of SQCCP raised many problems concerning analytical methods and procedures as well as data processing. Some of them were solved within the project; some other – only identified; they require further studies.

Table 1

The effect of ingredient and additives on margarine quality (factorial experiment)

Trial No.	Esterified fat	Emulsifier	Flavouring	Mean hedonic value
2/1	H	0291	A	5.23
2/2	H	0291	B	3.96
2/3	H	0098	A	4.66
2/4	H	0098	B	3.75
2/5	PKS	0291	A	4.60
2/6	PKS	0291	B	4.11
2/7	PKS	0098	A	4.88
2/8	PKS	0098	B	3.63
Ingredient effect	–0.19	0.49	1.96	

H, PK5 – esterified fats from two different suppliers; 0291, 0098 – manufacturer's catalogue numbers of two different emulsifiers; A, B – symbols of two flavourings suggested by the supplier

It is clear that sensory analysis and in particular descriptive analytical method is a main tool to implement SQCCP system. One of the main questions is proficiency of sensory panels (and individual panelists) for descriptive analysis. Although the need for standardised procedure of panel checking is commonly recognised, up to now it does not exist. However the above situation may change in the near future. The EC project has started in 1998 aiming at elaborating formal internationally agreed guidelines and protocol of proficiency testing for sensory methods, including descriptive analysis (LYON, 1998).

Another methodological question to be solved is the evaluation of sensory quality of metaproducts. It can be done directly, or more probably indirectly (instrumentally). When performed directly, it needs special procedure of sample preparation and special tasting technique. When made by instrumental methods, their informative value and sensitivity in reflecting changes in sensory properties of the product(s) as well as their variability should be previously checked (as illustrated in Fig. 9). It is of special importance to establish quantitatively allowed tolerances which do not affect sensory quality of the finished product.

Summarising, as a result of performed studies, the outline of the new preventive system of sensory quality assurance under the name SQCCP of some analogy to HACCP has been developed on the example of two types of the product, one of them being soft margarine. The general approach and main body of the methods have been proved as effective in assuring high and stable sensory quality of margarine in the processing plant of project's industrial partner.

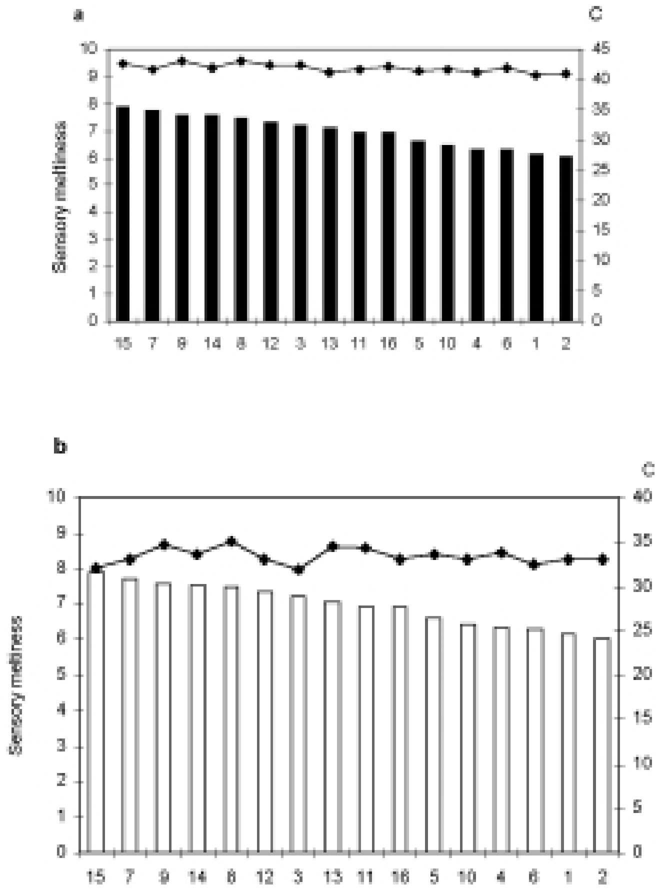

Fig. 9. Sensory meltiness compared with softening point of a) esterified fat (■: meltiness; -♦-: softening point of esterified fat) and b) margarine (□: meltiness; -♦-: softening point of esterified fat) (BARYLKO-PIKIELNA et al., 1997a)

It certainly does not mean that the system is ready to be implemented for sensory quality assurance of any food and beverage. The first steps were made; more research is needed, particularly in the methodology of SQCCP, as pointed out above.

References

BARYLKO-PIKIELNA, N., MATUSZEWSKA, I. & HELLEMANN, U. (1990): Effect of salt on time-intensity characteristics of bread. *Lebensm. Wiss. Technol.*, *23*, 422–426.

BARYLKO-PIKIELNA, N., MATUSZEWSKA, I., SZCZECINSKA, A. & RADZANOWSKA, J. (1997a): *Development of a sensory quality critical control points (SQCCP) system for processed foods and beverages.* Copernicus Programme (Contract ERBCIPA-CT94-0212). Final Report. Institute of Animal Reproduction and Food Research of Polish Academy of Sciences, Warszawa, Poland.

BARYLKO-PIKIELNA, N., MATUSZEWSKA, I., SZCZECINSKA, A. & RADZANOWSKA, J. (1997b): Consumer responses and sensory characteristics of low-fat and full-fat soft margarines and mixed spreads. *Pol. J. Fd Nutr. Sci.*, *6/47*, (4), 129–140.

BARYLKO-PIKIELNA, N., MATUSZEWSKA, I. & RADZANOWSKA, J. (1999): Taste perception of sweet/acid mixtures in gels. *Pol. J. Fd Nutr. Sci.*, *8/49*, (3), 49–59.

BOGGS, M. M. & HANSON, H. L. (1949): Analysis of foods by sensory difference tests. *Adv. Fd Res.*, *2*, 219–258.

BONNANS, S. & NOBLE, A. C. (1993): Effect of sweetener type and of sweetener and acid levels on temporal perception of sweetness, sourness and fruitiness. *Chemical Senses*, 18, 273–283.

CHAI, E., DAKENFULL, D. G., MACBRIDE, R. L., & LANE A. G. (1991): Sensory perception and rheology of flavoured gels. *Fd Australia*, *43*, (6), 256–257, 260–261.

FRANK, R. A., VAN DER KLAAUW, N. J., & SCHIFFERSTEIN, H. N. J. (1993): Both perceptual and conceptual factors influence taste-odor and taste-taste interactions. *Perception & Psychophysics, 54*, 343–354.

GREENHOFF, K. & MACFIE, H. J. H. (1994): Preference mapping in practice, -in: MACFIE, H. J. H. & THOMSON, D. M. H. (Eds) Measurement of food preferences. Blackie Academic & Professional, London, pp. 137–166.

KELLING, S. T. & HALPERN, B. P. (1983): Taste flashes: reaction times, intensity and quality. *Science*, *219*, 412–414.

LAWLESS, H. T. (1986): Sensory interactions in mixtures. *J. Sensory Studies*, 1, 259–274.

LYON, D. (1998): Project leader: International guidelines for proficiency testing in sensory analysis. Project EU No. SMT4-CT98-2227.

MACFIE, H. J. H, BARYLKO-PIKIELNA, N. & TÓTH-MARKUS, M. (1996): Developing a sensory quality critical control point (SQCCP) methodology. Proceedings of ESN Seminar, Sensory quality and consumer acceptance of food. Warsaw 20–22 June, Poland, pp. 57–61.

MÄLKKI, Y., HEINIÖ, R. L. & AUTIO, K. (1993): Influence of oat gum, guar gum and carboxymethyl cellulose on the perception of sweetness and flavour. *Fd Hydrocolloids*, 6, 525–532.

MCBRIDE, R. L. (1989): Three models for taste mixtures, -in: LAING, D. G., CAIN, W. S., MCBRIDE, R. L. & ACHE, B. W. (Eds) *Perception of complex smells and tastes*. Academic Press, Sydney, pp. 265–282.

MCBRIDE, R. L. & ANDERSON, N. H. (1990): Integration psychophysics, -in: MCBRIDE, R. L. & MACFIE, H. J. H. (Eds) *Psychological basis of sensory evaluation.* Elsevier Science Publishers Ltd, London, pp. 93–115.

MCBRIDE, R. L. & JOHNSON, R. L. (1987): Perception of sugar-acid mixtures in lemon juice drink. *Int. J. Fd Sci. Technol.*, *22*, 399–408.

PANGBORN, R. M., TRABUE, I. M. & SCZESNIAK, A. S. (1973): Effect of hydrocolloids on oral viscosity and basic taste intensities. *J. Texture Studies*, *4*, 224–241.

PLANK, R. P. (1948): A rational method for grading food quality. *Fd Technol.*, *2*, 241–251.

SALOVAARA, H., HELLEMANN, U. & KURKELA, R. (1982): Effect of salt on bread flavour. *Lebensm.Wiss.Technol.*, *15*, 270–274.

SCHIFFERSTEIN, H. N. J. (1994): Sweetness suppression in fructose/citric acid mixtures: A study of contextual effects. *Perception & Psychophysics, 56*, 227–237.

SHEWFELT, R. L., ERICKSON, M. C., HUNG, Y.-C. & MALUNDO, T. M. M. (1997): Applying quality concepts in frozen food development. *Fd Technol.*, *51*, (2), 56–59.

SJÖSTROM, B. (1951): Measuring of cereal flavors by the flavor profile method. *Trans. Am. Ass. Cer. Chem.*, *9*, 96–103.

STAMPANONI, CH. R. (1994): The role of sensory analysis in determining product quality and in quality control. *Lebensm.-Technol.*, *27*, (10), 322–329.

TILGNER, D. J. (1954): Organoleptyczny wskaznik slonosci. (Sensory index of saltiness.) *Przemysl Spozywczy*, *8*, 14–22.

TILGNER, D. J. (1957) : *Analiza organoleptyczna zywnosci.* (Sensory analysis of food.) WPLiS, Warszawa.

TUORILA-OLLIKAINEN, H., LÄHTEENMÄKI, L. & SALOVAARA, H. (1986): Attitudes, norms, intentions and hedonic responses in the selection of low salt bread in longitudinal choice experiment. *Appetite*, *7*, 127–139.

TUORILA, H.& PANGBORN, R. M. (1988a): Prediction of reported consumption of selected fat-containing foods. *Appetite*, *11*, 81–95.

TUORILA, H. & PANGBORN, R. M. (1988b): Behavioural models in the prediction of consumption of selected sweet, salty and fatty foods, -in: THOMSON, D. M. H. (Ed.) *Food acceptability.* Elsevier, Appl. Science, pp. 267–279.