Quality Perception: Multiple Attributes – Single Acceptance

B. Brückner
Quality Department, IGZ
Germany

QUALITY PERCEPTION

Can we perceive quality? Do we have a sense to distinguish good from bad quality? Being educated or not, everybody has an imagination of good or bad of almost everything in his environment. As long as a minimum of attention and involvement is exerted to an object, a feeling of pleasantness or unpleasantness is almost simultaneously present. Even more than optical or acoustic signals the experience of odours and flavours lead almost inevitably to an affective tone. We hardly can imagine eating a food without knowing instantly if we like it or not. And when we ask someone, how a food tastes, we expect and will receive the answer "good" or "not good" rather than "sweetish", "salty" or like something else.

Many of these quality experiences are well memorised, and we almost have the impression, even before we envision the details of an object or event in the past, we have a notion whether it was good or bad. But things can change. What was pleasant yesterday must not be felt as pleasant today. Especially in case of food we might have eaten too much of a specific item or consumed it too frequently. In addition, there is also a cognitive side of quality assessment. Food scandals, information on improper production methods or ethical considerations may affect the quality judgement. Product image associations, the price of a product or the availability of alternatives are examples for quality cues, too.

More and more these contextual, "external" attributes came into the focus of quality researchers, as important for quality evaluation and were denominated as extrinsic properties, as opposed to intrinsic properties, which refer to the attributes, physically belonging to and being verifiable in the product item itself. Those attributes, detectable in the product were the objects of the traditional quality research. Amongst the plenty of product properties often attributes were selected as quality criteria based on their measurability, accuracy and precision rather then a verified relevance for acceptability (Shewfelt, 2000) thus contributing to consumer oriented quality.

MULTIPLE ATTRIBUTES

Attributes of products are the elements, which are perceived through the senses of sight, smell touch, taste and hearing. Thus they are the first step from product itself to a recognised item. Widely accepted, the definition of sensory evaluation is: evoking, measuring, analysing and interpreting human responses to those perceived sensations (Stone and Sidel, 1993). This definition was valid also in the early beginning of sensory investigations in the 19th century. But the focus was on the product (stimulus) side, rather than the response side in terms of complex food or consumer matters. The starting point was detecting the amount of a physical stimulus to be perceivable and, when further increased, to be perceivably different. Fechner introduced these "just noticeable differences" as a unit of measurement, which allowed to construct a relationship between a stimulus and the sensory intensity. With his book "Elemente der Psychophysik" from 1860 he laid a foundation stone for sensory science and was among the first experimental psychologists at all.

From stimulus to sensation

The new science: psychophysics established the functional relationships for various stimuli and the intensities of the sensations. Fechner developed a relationship, built on the constant just noticeable differences, used as a unit for expressing the responses to presented stimuli. Its mathematical form is based on a natural log function. Typical test settings were difference tests with pairs of different stimuli.

The "method of single stimuli" was a breakthrough in testing efficiency. Rating scales were hereby directly applied to perceived intensities. Stevens used a scaling procedure. He refined it by the technique of magnitude estimation. Hereby the increase of perceived intensities is related to distances on the scale by repeated pairwise comparisons (Lawless and Heymann, 1998). He found, that the intensity of acoustic sensations and of several other sensory modalities, followed a power function of the respective stimuli (Stevens, 1962). The exponents were often less than one, thus allowing for a broad range of stimulus intensities to be perceived. This makes individuals well adapted to many magnitudes of signal energies from their environment.

A third approach, associated with the name of Beidler, was more physiologically inspired. Because taste responses may involve the binding of molecules to protein like receptor molecules, he suggested a function equivalent to Michaelis-Menten kinetics, describing enzyme-substrate velocities. With log concentrations the function is S-shaped and offers, in difference to the log function or the power function, an asymptotic level. This level is reached, when no further response can be expected, because the capacity of the sensors is fully utilised. In addition variations of this function could be used to predict responses in mixtures (Curtis et al., 1984) , (McBride, 1987) (Lawless and Heymann, 1998).

Taste and tastant interactions

The investigation of the effects of mixtures of taste substances on intensity perception is an important chapter of psychophysic research. All of the four classical tastes: sour, sweet, bitter and salty can be sensed separately in mixtures. But each of the substances in the mixture lead to a suppression of the perceived intensities of the others. Common examples are the balancing of bitterness or sourness by sweet tasting substances. There are only few exceptions from this mixture suppression. The umami sensation, caused by monosodium glutamate or 5´guanine monophosphate (Kawamura and Kare, 1987) together with ribosides has an increasing effect on the other taste perceptions. This effect is therefore also called hyperadditive. Another example is the enhancing of sweetness with low NaCl concentrations. An intrinsic sweet taste of NaCl (normally masked by its saltiness) may be the reason (Lawless and Heymann, 1998).

A very important effect in single tastant solutions as well as in mixtures - is adaptation. Under constant stimulation the response to the stimulus decreases – often until it is no more perceived at all. This effect is common to most sensory systems, which has alerting function to changes in the environment. After an adaptation to one stimulus other perceptions can be enhanced due to release from mixture inhibition. Its an everyday experience, that food tastes can be perceived different, depending on preceding taste experiences. Samples containing the same compound, which caused adaptation, but in a more dilute concentration can become other taste qualities. Water, thus, can taste sweet after bitter and sour stimuli, or taste bitter after sweet stimuli, or sour or bitter after salt adaptation.

Volatile matter – odour sensation

Certainly, the most important contribution to our experience of the flavours of food is brought by the volatile substances we sense with the olfactory system. Though it is only one functional system, separated in both nasal cavities, it serves two different functions. Substances, which enter the nasal cavity with the air stream through normal aspiring, are perceived "orthonasally". The perceptions are attributed to the environment outside the body, and serve the identification of the surrounding. Those volatile matters, released during the mastication processes reach the nasal cavity backwards, "retronasally". In this case the impression is that the flavour is located directly in the oral cavity, where it results from the food contact.

The ability to discriminate odour intensities is weak. Only very few intensity levels can be distinguished (Lawless, 1999). But the number of perceivable qualities is huge and possibly with no upper bound (Desor and Beauchamp, 1974).

Attempts have been made to establish a collection of odour descriptors. 146 commonly used descriptors were compiled by the ASTM (Dravnieks, 1985). 82 descriptors were grouped into vegetative, fruity, chemical, woody, microbial, caramel, floral, earthy, nutty, spicy pungent and oxidised (Noble et al., 1987). This has been an excellent work to identify and narrow down important descriptors for sensory wine analysis. But nevertheless Lawless, himself a wine expert, reports the anecdote, that verbal descriptions of aroma characters differed consistently and markedly among wine expert panel members (Lawless, 1999). Specific anosmia (disability to perceive certain aroma qualities) may be the reason. Also, the difficulty to associate odour perceptions with verbal descriptions inhibits labelling. It often leads to so-called impression “on-the-tip-of-the-nose”, meaning you know what it is, but you just can not find the word.

As in the case of taste, adaptation to odours is a very common phenomenon. It can lead to subsequent cessation of any perception. Also, again like in the taste modality mixture suppression or masking occurs. When odour substances of a mixture can be distinguished clearly, like pyridine and lavender oil, the perceived intensity of one component can be expressed as a function of the concentration of the other component (Cain and Drexler, 1974) (Lawless, 1977). Models have been tried to establish (Olsson, 1994), (Wise et al., 2000), but they proved to be very specific to the investigated setting.

Complex mixtures

It can not be taken for granted, that in mixtures of odours the character of the constituents will be resembled and transparent within the new impression of the mixture. But in some cases, it can be successful to analyse the underlying odour qualities. Then, the specificity of the analysis can be improved by training and experience (Lawless, 1988). There are also cases where some odour components dominate the overall impression. This was observed even with substances with lower odour activity values (OAV, the ratio of the concentration to the odour threshold) over others with higher OAV, which in turn lost importance for the resulting impression (Grosch, 2001). Even omitting distinctively smelling substances in mixtures can remain hidden (LASKA and HUDSON, 1992), thus leaving the mixture apparently unchanged to the senses.

A phenomenon, common within natural food is the formation of flavour patterns which are new and distinctive. The new “synthetic” flavour is not present in a single odour component. Tomato aroma (Buttery et al., 1989) and chocolate (Lawless and Heymann, 1998) are examples of well blended aromas, where the nature of the constituents is not perceived for the benefit of a new flavour. Another example is cola aroma, a distinctive, unitary impression, but blended from citrus, brown spice and vanilla (Lawless, 1999), none of them resembling cola aroma individually.

Concurrent sensations

Another “synthetic” effect is the impression, that taste and retronasally experienced odour form a unitary perception seemingly originating in the oral cavity. The perception and/or cognition of stimulus mixtures across the modalities of taste and olfaction again is a large field within psychophysical research.

Often it will not be realised, that perceptions may arise from taste and olfaction. Sweet or sour impressions resulting from odours alone are common, but nevertheless not triggered by the taste senses directly. Learned experiences mediated by the repeated concurrence may lead to the overall impression, even if the modality of taste was not physically present. If both modalities, odour and taste are present, often additive effects were measured, perceived as taste intensities e.g. sour or sweet (Murphy and Cain, 1980).

In real food samples also enhancement and suppression effects between the two modalities are present. There is a general mechanism, that pleasant tastes enhance, and harsh tastes suppress volatile flavours. An attention shift may occur from a pleasant food, where attention is directed to the aroma qualities to the harsher taste impression, which draws attention away from aroma (Lawless and Heymann, 1998). Another explanation is the halo effect. In this context a positive stimulation increases the positive impression of other perceived attributes. In principle it is a hedonic reaction to one stimulus, which includes further perceptions in a positive affective status.

Other modalities

Equally important to the taste and aroma attributes are the texture properties of food. Even more then chemical stimuli, textural issues are sensory categories, defined as reactions to stress (force) or tactile feeling (Meilgaard et al., 1991). Texture constitutes an additional value, like an attractive crisp or crunchy product, or its role is more to mediate flavour perception e.g. sweetness as a function of sugar contents and juiciness (Brückner and Auerswald, 2000). As discussed in the other modalities, also in the texture modality the role of attention is emphasised. An acceptable texture is hardly noticed, but negative texture experiences are strongly linked with negative hedonic loading (Szczesniak and Kahn, 1971) (Szczesniak, 2002). Texture changes occurring after harvest therefore are an important candidate for careful monitoring (Van Dijk C. and Tijskens L.M.M., 2000).

A fourth modality contributing to the overall flavour gaining attention in the recent literature is the trigeminal senses. Examples for the experiences mediated by the trigeminal nerves are the prickling of carbon dioxide in beverages (undoubtedly influencing e.g. sweetness perception in carbonated beverages), burn from hot peppers or spices and the pungency from radish, horseradish or onions. The separation from further modalities are blurred, e.g. astringency has at least components of tactile sensations, whereas the burn from spices also related to temperature or pain sensation. It is an everyday experience, that appearance, colour and even sound exert an influence on several sensory modalities. Sweetness and fruit flavour, for example, proved to be influenced by colouring of test samples (Stillman, 1993).

Synthetic vs. analytic

Almost without exception we have seen examples, where simultaneous stimuli are not only perceived in parallel or additive, but affect each other to form an altered, new impression. Even across the boundaries of all modalities of our sensory system. But the degree to which these interactions occur varies. Attention to the distinguishing task, and the ease to assign detected notes to a predefined unit markedly improved the ability to discriminate mixture components. A discussion is going on, whether integration occurs in an early stage of sensory-perceptual processing or in a late cognitive-conceptual phase. Both seem to be the case, depending on the stimuli in question: mutual suppression of bitter and sweet being an example for the former, since it is not disturbed by contextual circumstances (Frank, 2003). There is an indication for common processing of signals in the same neurons, resulting from both, bitter and sweet stimuli (Margolskee, 2002). Sweetness enhancement by an congruent odour (e.g. strawberry) is an example for the latter, a more cognitive integration. The later in the process, and thus more cognitively controllable the better a possible separation. Recently a four step model was developed, to explain the different amount of pooling of stimulus sensations in dependency on instructions that favour analytical or integrative approach (Frank, 2003).

Evidence from brain research

Investigations in the human brain, using positron emission tomography to detect the intensity of cerebral blood flow, and thus indicating neuronal activity, suggest a two-fold mechanism: the presentation of independent olfactory or gustatory stimuli evoked activity in different regions of the brain, than the same stimuli presented in a mixture (Small et al., 1997).

The independent, separate processing of combined stimuli speeds up recognition of blended categories. This is consistent with the ecological function of the sensations to identify objects or areas with their characteristic stimulus combinations, where a fast acting guidance to the beneficial or detrimental effects for survival is necessary. Rather than analytical detection and memorisation of intensity proportions, new patterns are formed and archived, in association with concurrent sensory stimulations and hedonic tones. Separated activation pathways were detected for well blended or familiar as opposed to mismatched, unfamiliar flavours (Small et al., 1997). Occurrence of the latter coincides with stronger activation of the amygdala, a component of the limbic system, important for emotional or affective behaviours and feelings (e.g. fear, anger). It is also associated with cognitive processes including attention and memory, autonomic functions, modulation of motor readiness (Zald, 2003). In his investigations (Small et al., 2001) on pleasant and unpleasant impressions during chocolate eating before and after satiety, he could localise different activated brain areas. Depending on which area was active a neural representation of reward or punishment seemed to cause positive or negative affective status. He hypothesised, that there are separate motivational systems: one orchestrating approach and another avoidance behaviours.

SINGLE ACCEPTANCE

These results strengthen the view, that sensory acceptance of food is a learned emotional reaction on stimuli or stimulus complexes, most often originating from different modalities. It is subject to temporary or lasting change after new experiences and due to multiple cognitive and non cognitive influences. But when broken down to a single hedonic tone, acceptance constitutes the one basis for purchase and consumption.

No matter which definition of acceptance is adopted, acceptance marks an important point in the continuum “halfway” from a first contact to a (repeated) positive or negative consumption decision. The first half used to be the domain of product development (breeding) and production, the second half the domain of marketing and retail. Interestingly the common point of these two domains seem to mark the interface of two “technical” processes (production and distribution) with the consumer standing aside at the end of the chain. But there is no doubt, that, for repeated purchase of a product, the sensory acceptance is a necessary requirement. This is true with or without the added value brought by the concept formation of marketing or the situational efforts of retail, which sometimes may be another necessary requirement for purchase. Thus consumer acceptance (singular acceptance of each consumer, or possibly a consumer group) should be considered in all stages of product development and production, from breeding to postharvest.

Some implications for acceptance testing

We have seen that the product attributes are not necessarily perceived separately, but can constitute more complex structures. In texture measurement researchers are acquainted with the phenomenon, that several physical product properties form, what accounts for e.g. crispness on the sensory side. Therefore care has to be taken, also in the other modalities, to envisage the right effective stimulus.

Attention to stimuli and their facets is an important factor, which can drive the analytical performance of sensory panellists. The training of descriptive panellists should include enough qualitative discussion until an agreeable and un-decomposable sensory units for descriptor formation was found. With different training material repeated questioning of the descriptors in use can become necessary. The more thoroughness is spent on this process, the more generic the vocabulary can be used. But it still keeps a descriptive picture, tailored for each category of produce. Careful selection of samples included in one investigation is essential, because attributes under consideration are often not unrelated, so that misleading predictions about the causality can arise.

Because of the multivariate nature of both, the products and the consumer perception a multivariate representation of the data structure is very important. Very often Principal Component Analysis (PCA) is used. Hereby a map is constructed with dimensions, which represent the common variation (relatedness) of those attributes.

Figure 1 gives an example from two years of a carrot study (Brückner et al., 2000). With the attributes determined by a descriptive panel, the map of 48 raw carrot samples was calculated. Two independent dimensions (axes) depict many flavour attribute intensities (Principal Component 1 (PC 1)) and some texture or appearance attributes (PC 2). The arrow indicates the direction of increasing mean consumer acceptance, which was determined with 100 consumers in parallel.

Though the carrot samples were taken from several different varieties, growing areas and postharvest treatments, the perceived sweetness did not differ very much and was not correlated with the main principal components. Therefore sweetness is not depicted on the map, despite its supposed importance in each case. The arrow was projected onto the map after a linear response surface calculation.

A similar PCA was calculated using the results from several tomato experiments (Figure 2), (Brückner, 2000). In addition acceptance scores from a parallel consumer panel were recorded. They were standardised and subject to cluster analysis to detect different schemes of consumer responses to the tomato attributes. The resulting cluster means were included in the PCA map of the descriptive analysis.

The position of each of the attributes in figure 1 and 2 is determined by the intensity differences between the samples. When two attributes differ in their intensities and show higher (or lower) intensities in the same products, they are close to each other on the map. There is no information on the importance of an attribute on the map.

This is different in the perceptual maps offered by Internal Preference Mapping (Greenhoff and MacFie, 1994). Here the dimensions and the sample positions are determined by consumer preference data only. Not the “analytically” derived attribute intensity variations, but the hedonic valence of attribute combinations as perceived by consumers primarily drive the mapping process. The result is a liking map in comparison to an intensity variation map in PCA. An example of a PCA map derived from descriptive data only, and a perceptual map derived from consumer preference data is given in figure 3 and 4. According to the positions, to which the products were assigned by consumer data only (Figure 4), significant attributes were projected on the map. The data are taken from an experiment with different broccoli and cauliflower varieties (Brückner and Schonhof, 2001).

Factor 1 (Figure 3) shows the variation of the attributes sweet, juicy and grainy on the left side, and bitter, pungent and other flavours on the right side. The second factor separates firm crisp and cauliflower notes from darker colour, larger bud size and broccoli flavour.

Though the maps in figure 3 and figure 4 rely on different data sources within the same experiment, a similar structure of the attributes can be seen. The map shows four groups of attributes, each sharing common acceptance. Other than in case of a descriptive map this preference map combines attributes belonging together from a consumer perspective. Not in every experiment such an assignment of descriptive attributes to preference dimensions can be obtained. The results of course depend on the attributes, unrelated or correlated, but present in the material. A prediction of the acceptance of a product on the basis of its attributes will only succeed with a descriptive situation not too far away from the conditions at which the tests have been conducted. New combinations of attributes together with new intensities of attributes must be investigated without having been indicated to be attractive by previous investigations. In her discussion of food quality criteria Bech et al. cite the need of products not only to meet, but to exceed customers’ requirements or even expectations (Bech et al., 2000). Thus innovations turn up to be necessary part of a quality concept. An example of development of product with a new set of attributes is the launch of a new yellow-fleshed, sweet and fruity flavoured cultivar of kiwifruit on the marketplace (Jaeger et al., 2003). In this study, a comparison of consumer preferences for this new type of kiwifruit with that of the familiar green-fleshed and sweet-tart tasting kiwifruit was undertaken and a segmented population with respect to liking of yellow-fleshed kiwifruit genotypes was observed. Also in case of vegetables more careful, qualitative and quantitative consumer studies should guide development of new products, that appeals to target consumer populations. It is widely accepted, that consumers differ, but the segmentation of consumers is not reflected in a analogical segmentation of horticultural produce. It will not be possible and reasonable to create numerous intensity combinations of the multiple attributes of fruits and vegetables. And it may be not necessary, too. The consumer acceptance is singular and evaluates patterns, percepts or concepts, rather than solely attributes. A quality strategy therefore is to identify those attribute combinations, that form concepts, that give rise to increased consumer acceptance.

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Figures

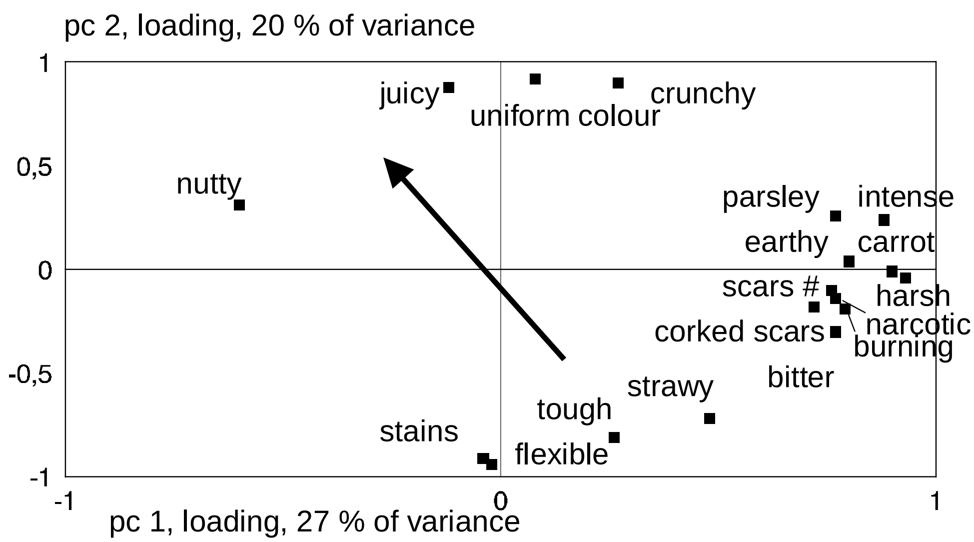

Fig. 1. Principal component analysis of the descriptive attributes of raw carrots (from: (Brückner et al., 2000)).

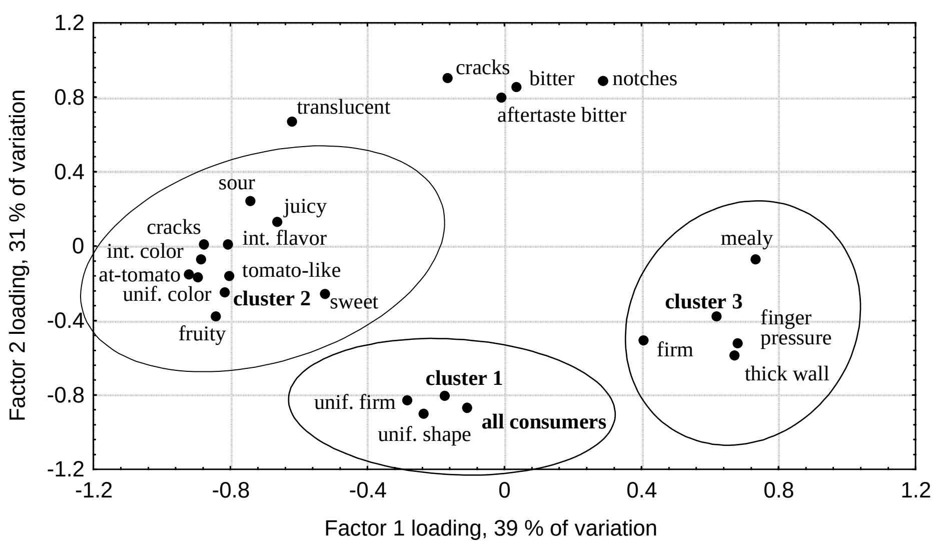

Fig. 2. PCA analysis of the results of descriptive analysis of tomatoes and consumer cluster positions (from: (Brückner, 2000)).

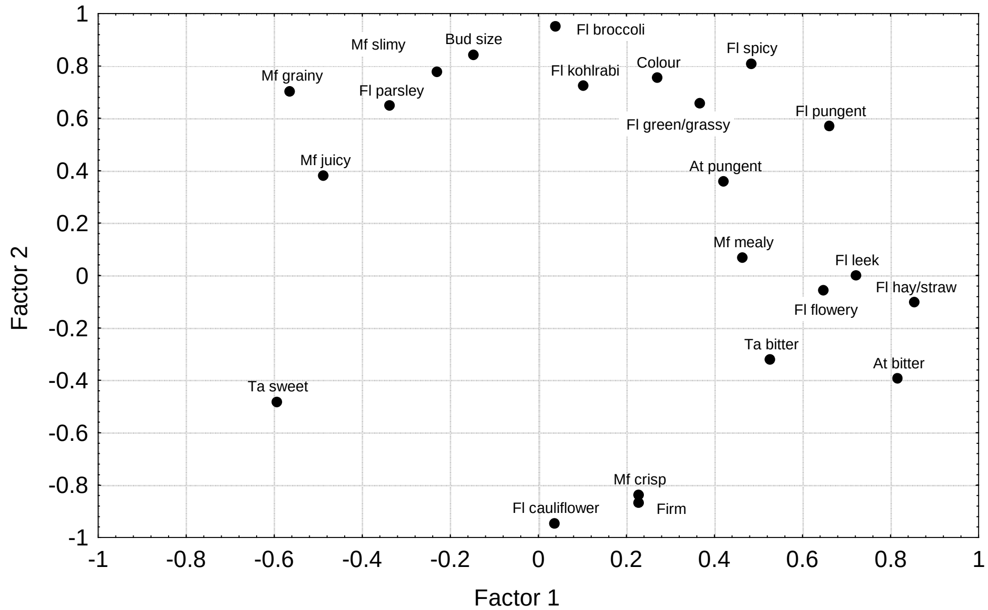

Fig. 3. PCA analysis of the results of descriptive analysis of broccoli and cauliflower. (At=aftertaste. Fl=flavour, Mf=mouthfeel and Ta=taste).

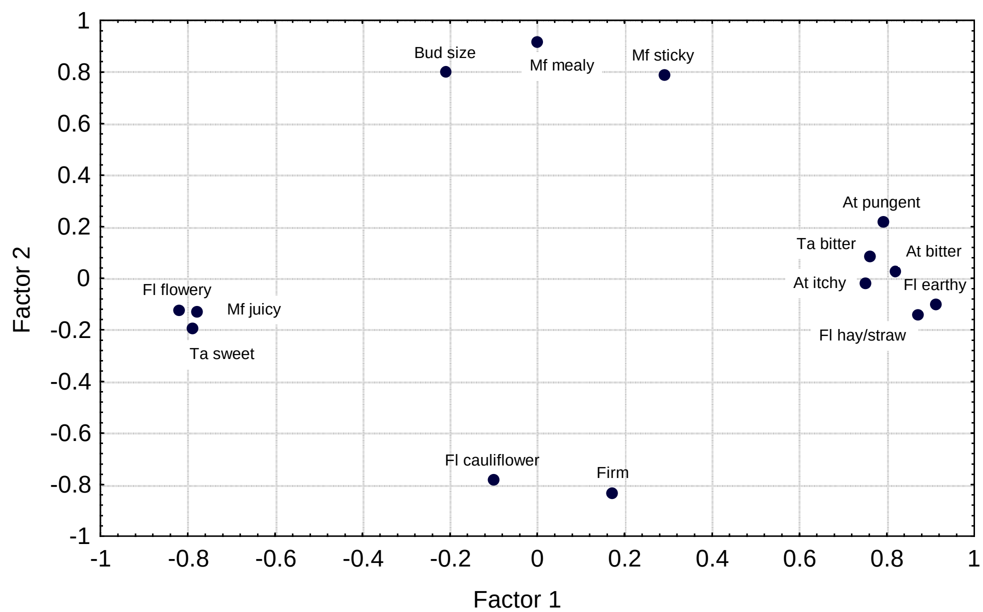

Fig. 4. Projection of the significant attributes on the internal preference map, derived from consumer data. (At=aftertaste. Fl=flavour, Mf=mouthfeel and Ta=taste).