Consumer-Oriented Quality Improvement of Tomatoes in Indonesia

How to construct an ideotype? How to assess quality problems?[1]

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Summary

Consumer demands become increasingly strong in Western countries. Product quality has proven to be an important marketing tool to compete effectively on these saturated markets. Markets in developing countries are mostly producer dominated. Not much attention is paid to product quality. Agricultural researchers traditionally are producer-oriented, rather than consumer-oriented. Research on tomatoes in Indonesia has shown, that even in producer dominated markets, consumers have specific wishes regarding quality, which should be taken into consideration in order to develop demand and to enhance farmers' profitability. This paper sheds light on a research methodology to translate consumer preferences into an ideotype, a practical product profile consisting of optimal levels of relevant physical and chemical properties. This ideotype should be used to objectively evaluate agricultural research, aimed at improving product quality. In addition, a list of quality problems of current supply is presented. This priority list serves as a guideline for research planning.

Introduction

Quality improvement of agricultural products is often associated with a saturated market, where consumers have ample choice and reject products perceived to be of poor quality. This has forced producers to become consumer-oriented. In many developing countries, a situation of relative scarcity prevails. Quality improvement is primarily producer-oriented and aimed at improving products in such a way, that they can be produced profitably in sufficiently large quantities. However, even in conditions of relative scarcity, it is still the consumer, who ultimately uses her/his own perceptions and beliefs of quality to evaluate a product. Supply of a (new) agricultural product, which corresponds better with consumer preferences, will enable farmers to raise prices and increase profitability.

A good example is the introduction of a new variety of tomato in Indonesia. These so-called 'Taiwan' tomatoes currently hold a market share of 50% in the towns surveyed. They are sold at a 25% higher price, while production costs have remained about equal to those of local varieties grown under similar conditions. The success of 'Taiwan' tomatoes is partly due to the fact that the product excelled on important consumer criteria and was, therefore, able to command a

[1] This paper is a summarized version of a research report with the same title. The interested reader can obtain a copy from Dr G. Grubben, CPRO, P.O. Box 16, 6700 AA Wageningen, The Netherlands, referring to LEHRI/ATA-365 Internal Communication No. 46.

higher price.

International, national and to a lesser degree private agricultural research institutes, both in developing and developed countries, are traditionally producer-oriented rather than consumer-oriented. They have little experience with consumer research (e.g. Stevens, 1986b; Ameriana, 1991; Potts and Chilver, 1992). Partly this could be justified by the need to assist farmers to increase production, partly it is so because in the opinion of many agricultural technicians consumer preferences are difficult to measure, they seem highly subjective and sensitive to changes in 'fashion' (Schouten, 1990).

In view of this, it seems recommendable for agricultural researchers to acquire experience with consumer-oriented product quality development.

This paper deals with revealing consumer demands and intends to make clear to breeders, agronomists and post-harvest technicians that consumer preferences are indeed objectively measurable and can serve as a guideline for breeding programs and other agricultural research.

Research objectives

The Lembang Horticultural Research Institute near Bandung, West Java, Indonesia has started consumer-oriented quality research in 1989. Products surveyed were garlic and shallots (Ameriana, 1991). Indonesia shows a growing demand for higher quality tomatoes (Van Lieshout, 1992b). The task at hand was to reveal consumer criteria and to improve the quality of local tomato varieties.

This research consisted of two phases:

Phase I: a representative consumer research with simultaneous laboratory analyses, aimed at finding answers on the following questions:

a. what is the optimal consumer quality?

b. what are consumers willing to pay for better quality?

c. what is the ideotype or optimal product profile?

d. what are the current quality problems?

Phase II: production research aimed at eliminating current quality problems. The ideotype, or optimal product profile should be used for quality evaluation of field trials and (on farm) experiments. The key question is:

e. what is the optimal use of instruments?

Phase II is currently under execution. This paper deals with the first phase only. It focuses on quantifying the optimal fruit profile for tomato used fresh as fruit or in salads. A similar study, was done for tomato used for cooking (Ameriana, 1992). In addition, a list of quality problems of current tomato supply was to be made.

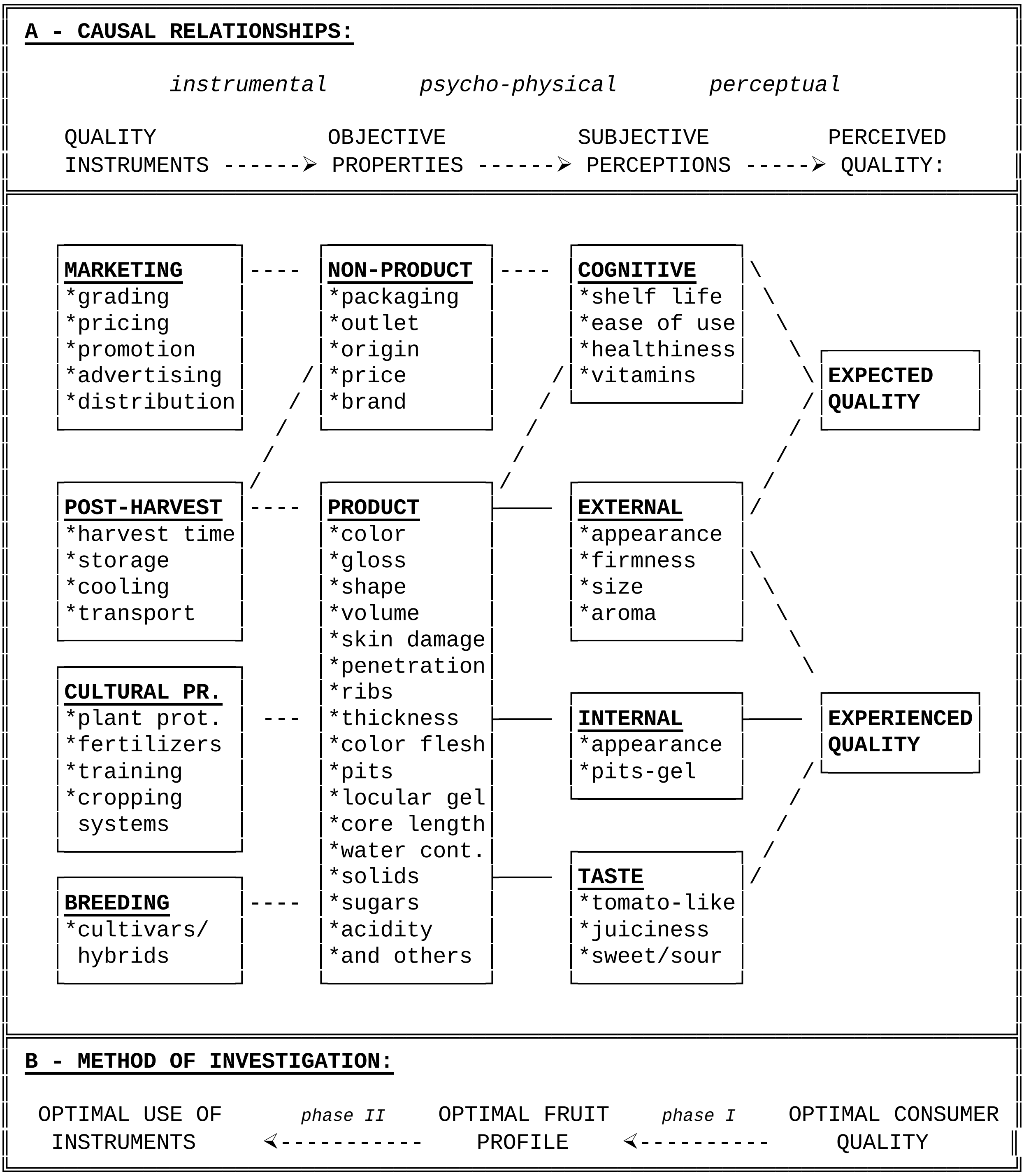
The research model

The model presented in schedule 1, is adapted from the quality perception research model of Steenkamp and Van Trijp (1988). See also Wolters and Van Gemert (1990).

When purchasing a product, a consumer has certain quality expectations. At the time of consumption, it is actually experienced: did the product possess the characteristics, which were liked, or were those disliked absent? When expectations are satisfied a consumer will be strengthened in her/his belief, that s/he is buying the right product and this will increase repeat purchases. On the other hand, if the experience turns out dissatisfactorily, the consumer will look for alternatives.

The model distinguished three types of causal relationships (Part A). Both expected quality and experienced quality can, to a large extent, be explained by what consumers know - cognitive factors - and by what they see, feel, smell and/or taste - sensory factors (perceptual relationships).

Schedule 1 - A MODEL FOR QUALITY RESEARCH FOR TOMATO



Note: Dotted lines are relationships not under investigation in this research

In turn, cognitive and sensory factors are influenced by product properties - color, shape, sugar contents - and by non-product properties - packing, origin of the product, outlet, price, brand name - (psycho-physical relationships).

To improve quality expectation and quality experience, production methods - cultivar used, cultural practices, post-harvest handling - and marketing tools - grading, packing, propaganda, pricing - have to be defined, which improve objective properties (instrumental relationships).

The method of investigation works in the reverse order (see B in research model). What is the optimal consumer quality? What is the optimal product profile? What is the optimal use of quality instruments?

Measurement

An important issue in quality research is measurement. This section deals with how perceptual and psyco-physical relationships were measured, how an ideotype was constructed and quality problems formulated.

Perceptual relationships

Most sensory analyses on food products take place under controlled, standardized circumstances and are carried out with the help of panels (Meilgaard, et.al., 1987). Panels have proven to be very useful when detailed aromatic descriptions of flavour were required (Martens, 1984; Vesseur, 1990; Janse, 1991). The argument for using panels is that analytical descriptions by consumers would not be reliable, because they fall outside their natural behavior (Köster, 1990). Panel training is expensive and time-consuming.

In our opinion, for simple sensory evaluation of food aspects, like shape, color, sweet- or sourness and taste intensity, panels are not required. Consumers can be asked to give sensory descriptions themselves (Gormley & Maher, 1987; Steenkamp and van Trijp, 1988; Steenkamp, 1989; Eytan, 1990).

When a consumer is assessing a product, a multitude of aspects must be evaluated and related to its overall quality. With multiple regression analysis these relationships can be quantified. However, there are two problems.

First, consumers have restricted information processing capacity. It is unlikely, that all sensory aspects are evaluated separately. Earlier research has shown, that usually three to four more general dimensions are being used (Wieringa & van Raay, 1987; Steenkamp, 1989; Hobson, et. al., 1990; Schutz, 1990). With principal component analysis the underlying impressions can be extracted from the sensory descriptions, given by consumers. Selection of factors is based upon the 'eigenvalue' criterium. The eigenvalue is the sum of the squared factor loadings and must exceed one, only then the factor explains more variance than the composing variables themselves (Hair, et.al.,1987). Significant factor loadings over 0.40 were underlined and only these determined the name of the common denominator. Factor scores replaced the original sensory scores. Factor analyses were carried out separately for external, internal and organoleptic aspects and also separately for each varietal type to see whether or not perceptual differences existed between the types;

Secondly, perceptions are inter-correlated. This can be due to natural causes (a tomato which is ripe, is also red) or because consumers interpret two aspects similarly (a tomato with a green shoulder and one with a gloss are both indicators for freshness, thus they are correlated, although there exists no causal relationship). Multiple regression analysis looks for a solution with as few explaining variables as possible, which will lead to exclusion of relevant variables with high intercorrelations. This is unacceptable when making an optimal product profile, which should incorporate all relevant properties. Therefore,

(a) single correlations between perceived quality and all sensory dimensions and cognitive aspects were calculated: the larger the correlation, the more significant the influence on perceived quality;

(b) standardized partial regression coefficients (beta-values or path coefficients) were calculated to quantify which dimension contributed most to the explanation of perceived quality, taking into account intercorrelations. The beta-value of a variable is the contribution to explaining variance of a dependent variable, after adjusting for the variance already explained by previous variables. The higher (the absolute value of) the beta-value, the more important the variable.

Psycho-physical relationships

Sensory and cognitive perceptions, which contributed significantly to perceived quality, were 'translated' into physical and chemical product properties, objectively measured in the laboratory. For this translation simultaneous measurement of sensory and objective aspects was indispensable. With this, three problems arose.

First, some sensory properties were difficult to measure instrumentally, because laboratory analyses were prohibitively complicated and expensive, or because the amount of product available for the analysis was too little, since all destructive tests had to be carried out with the remainder of the evaluated tomato. This particularly concerned organoleptic properties: crispiness, toughness of skin, juiciness and above all aromatic aspects of flavour and odor. Other properties which were difficult to measure were gloss (degree of reflection) and skin smoothness.

A solution was to train a mini panel of five laboratory staff to describe non-measurable properties in a standardized way. As much as possible existing national or international standards were used. In Indonesia standards for fresh fruit and vegetables are virtually non-existent and of no practical use (Van Lieshout and Santika, 1991). In the absence of standards new ones had to be developed. Properties for which no satisfactory standard description could be developed had to be left unmeasured.

Secondly, psycho-physical relationships are generally weak and correlations low, because perceptions are not only influenced by product properties, but also by factors like education, socio-economic class and by random circumstances, which naturally occur at a market place. Of practical importance is the statistical significance of the correlation. To reduce the probability of excluding properties which might be of influence, correlations were considered significant at $p<.10$ (Steenkamp and Van Trijp, 1988).

Thirdly, product properties are intercorrelated. As with perceptual relationships single correlations were first calculated. A corollary of the inter-correlations is, that not all correlations were due to causality. Significant correlations were, therefore, cross-checked and validated by earlier research or in absence of literature, by expert opinion of a plant physiologist. Subsequently, beta-values were calculated for those properties, which were considered causal. The higher the beta-value the more impact on the perceptual dimension and hence on perceived quality. R^2 was also calculated to establish how much percent of variance in a perceptual dimension could be explained by the causal properties under analysis.

The optimal fruit profile

The optimal fruit profile is defined as the hypothetical product, which is composed of first class properties only. A property was called first class when it was considered better than average by a majority of consumers. Only those properties were deemed important, which had a significant causal relationship with an important perceptual dimension.

In order to establish the optimal

level of such a property, psycho-physical relationships were cross-tabulated. Two rows contained the factor scores of the perceptual dimension: in the upper row the scores better than average, in the lower row the scores worse than average. The columns contained the laboratory values. Subsequently, percentages were calculated through division of frequencies by column totals.

The optimal level of a property (say, sugar contents) was determined by whether or not a majority of consumers existed, who considered the product better (i.e. sweeter) than average at a particular level. Beyond that optimal level the property in question was called first class.

Because of the heterogeneity of supply and demand, a minimum of 60% of the consumers was deemed sufficient to be called a majority.

Quality problems

Quality problems were third class properties. Which third class property to work on in a quality improvement program is outlined below.

First, it was calculated how much percent of each tomato type was considered to be of "poor" or "very poor" quality. Secondly, the problem levels of both perceptual dimensions and properties were determined, by whether or not a majority of consumers considered the quality poorer than average at a particular level. This was done in the same way as for the optimal level. Thirdly, after having established the problem levels the percentage of third class tomatoes was calculated. The larger the percentage, the greater the problem.

Research design

The crux of the research is simultanuous measurement of consumer perceptions and laboratory values. Each consumer evaluated one tomato and the same tomato was measured objectively in the laboratory. Non-destructive tests were carried out one hour before and destructive tests within four hours after consumer evaluation. The consumer gave sensory descriptions for twelve external, eight internal and eight organoleptic attributes. Table 1 reports the consumer attributes and the corresponding laboratory analyses carried out. In addition four cognitive aspects were evaluated. Two hundred respondents (and tomatoes) at eight different market places and supermarkets were selected in two towns: Bandung in West Java and Yogyakarta in Central Java. The research took place in January 1992.

Selection of tomatoes

As a result of differences in altitude, availability of varieties and technical know-how between production areas an enormous natural variation exists in size, color, shape, firmness, damages, maturity, sugar and acidity levels. Globally three different types of tomatoes could be discerned. See table 2.

'Taiwan' varieties, which are modern hybrids of Lycopersicon esculentum from a Taiwan based breeding company, and Highland tomatoes are best grown at altitudes over 500 m a.s.l.. Lowland tomatoes are grown under 200 m a.s.l.. Highland and Lowland contain both local varieties and officially released varieties from AVRDC selections (Van Marrewijk, 1992).

Not always all types were available at all markets. Therefore selection of tomatoes was manipulated in such a way, that all three types were being evaluated by respondents in all markets. Only ripe tomatoes with over 30% red coloring were used: green mature tomatoes, breakers and turning were excluded, because they are not usually consumed fresh.

Results

1. The optimal consumer quality of fruit tomato

Perceptual dimensions

With factor analysis four external, two internal and three organoleptic perceptual dimensions were found. Tables 3 to 5 report factor matrices. The external dimensions used by consumers, were: "outer appearance", combining color aspects (ripeness, color and color distribution) shape and skin smoothness; "firm/freshness", because it grouped perceived firmness, freshness, gloss, smell of rot and again skin smoothness - skin smoothness could indeed be interpreted in two ways: absence of a rough of skin with damages is an indication for firmness and freshness, at the same time a smooth skin is beautiful, enhancing the appearance; "size" and "aroma".

The internal dimensions distinguished by consumers were "inner appearance", composed of orderly appearance, nice color of flesh, strong aroma and much flesh, and "pits-gel", referring to the perceived amount of pits, gel and the core length.

The first organoleptic dimension was named "typical tomato taste". At one pole the typical flavor characteristics: tasteful, aromatic, crispy. At the other pole the off-flavors: mealy, tart, little taste. The second dimension was called "juicy/no tough skin", combining sensory juiciness and skin toughness: the tougher the skin, the drier the tomato. The last factor yielded a "sweet/not sour" dimension.

This needs some elaboration. Earlier research has shown that each of the four sweet/sour combinations has its own flavor characteristic: low sweetness/low acidity produces a tasteless, insipid tomato. Contrarily a high sweetness/high acidity tomato is well-tasting and fruity, sweet/sourish. The other combinations are low sweetness/ high acidity, which gives a tart taste and high sweetness/low acidity, which gives a bland taste (Grierson and Kader, 1986). The last combination (tart versus bland) coincided best with the dimension found. Apparently, Indonesian consumers associated high sweetness with low acidity and vice-versa. The intercorrelation of $r=.378$ ($p<0.001$) confirmed this.

Separate factor analyses for each type of tomato yielded similar results. It could thus be concluded that consumers looked at tomatoes irrespective of the type (Van Lieshout, 1992a).

Expected quality

Quality expectations of tomato are strongly related to sensory aspects, more than to cognitive aspects (table 6). Quality expectations are mostly raised by nice appearance, fresh/firmness and perceived healthiness.

The relative importance, measured by beta values, of sensory dimensions was much larger, than the importance of cognitive variables. Healthiness and vitamins were excluded from the solution, because they were highly correlated with the external dimensions. Healthiness was related to fresh/firmness ($r=.39$), perceived vitamin content was most strongly related to perceived aroma ($r=0.22$) and to a nice appearance ($r=0.20$). The optimal tomato is fresh/firm tomato with a good appearance, a strong aroma and is relatively big.

Experienced quality

Experienced quality correlated significantly with all but one dimension (table 7). This makes clear, that quality experience is indeed a complex issue. Inner appearance, perceived sweet-sourness, typical tomato taste, and fresh-firmness had the strongest relationships.

Looking at the beta-values, it appears, that internal and organoleptic dimensions are more important to quality experience, than external ones. Typical tomato taste is now excluded, because of its very high correlation with inner appearance (r=0.583). In other words if a tomato looks well from the inside, its typical tomato taste is strong. If on the other hand the tomato looks bleak and messy, with thin fruit walls and no aroma its taste is weak, insipid. The optimal tomato has a nice inner appearance, is sweet, not sour and has little pits-gel substance.

Quality differences between varietal types

The average scores for expected and experienced quality of tomatoes is given in table 8 'Taiwan' varieties were considered to be of reasonable quality. The average score for experienced quality was less favorable (0.30) than for expected quality. In other words 'Taiwan' varieties could not meet the high expectations raised by external perceptions and cognitive beliefs. On average Highland varieties were of a lower expected quality, yet of similar experienced quality as 'Taiwan' tomatoes: both reasonable. Lowland varieties were found bad for fresh fruit consumption in terms of expected and experienced quality. For the latter types no significant difference between expected and experienced quality was found.

Table 9 shows differences in perceptions between the three types of varieties. With regards to expected quality, 'Taiwan' ranks first on all four external perceptual dimensions. Only their vitamin contents is perceived to be lower than the other varieties. Highland varieties differed from 'Taiwan' with respect of firmness/ freshness, perceived amount of pits & gel and according to the consumer they were not well keepable. Lowland varieties scored last on all external and cognitive aspects, except on expected shelf life.

Quality experience (which is dominated by inner appearance, sweetness and strong tomato taste) is similar for 'Taiwan' and Highland tomatoes. Again Lowland tomato experience is behind on all dimensions. This ranking fully explains the differences between varieties in expected and experienced quality (table 8).

2. Willingness to pay

There existed a very significant relationship between the maximum price consumers were willing to pay and perceived quality. For each 'step', e.g. from "reasonable" to "good", the consumer was willing to pay about 15% more, or an average of Rp 120 per kilogram extra. The interpretation can also be reversed: if quality decreases by one step, say from "reasonable" to "poor", the consumer was willing to pay a maximum price which was Rp 120 per kilo less.

3. The optimal fruit profile

The optimal tomato has high expected and experienced quality. In the previous section it was described how consumers arrive at their quality opinion, which perceptions are important. This section deals with a translation of perceptual values into objective parameters, a classification of relevant parameters into first, second and third class levels and finally the construction of the optimal fruit profile.

Psycho-physical relationships

Significant single correlations between sensory and cognitive dimensions and product properties are reported in table 10. Most product properties influenced more than one dimension, although not all correlations, had a causal basis. Causal relationships were either validated by literature (e.g. Stevens, 1979; Goodenaugh and Atkin, 1981; Janse, 1982; Gould, 1983; Hobson and Kilby, 1984; Stevens, 1985; Blanc, 1986; Dièz et.al., 1986; Stevens & Rick, 1986a; Van Vuurst-de Vries, 1986; Jordan, 1990; Gorini and Testoni, 1990) or by Indonesian tomato experts at LEHRI, Lembang, Indonesia (Sinaga, Asgar, Budi Jaya, Purwati, Sumiati).

Table 11 shows the beta-values of the significant causal relationships between properties and perceptual dimensions significantly affecting expected and experienced quality.

P1-outer appearance; 40% of variance could be explained. It is enhanced by a full red color of both skin and flesh. The significant quadratic effect of sphericity indicates, that the optimal shape is round (index 90-120), elongated (≤90) and oblate (≥120) tomatoes are preferred less. Severity of visible damages contribute negatively. Ripeness, despite having a high single correlation (r=0.54) no longer contributed, when color is adjusted for.

P2-fresh/firmness had a relatively high correlation with manual firmness, measured by the mini-panel in the laboratory (r=0.50, p<.001). Manual firmness, in turn was causally related to penetration, thickness of fruit wall and the amount of pits & gel. A green shoulder added to perceptions of freshness. Ripeness, severity of visible damages and amount of loculi did not contribute.

P3-size perceptions of consumers correlated very highly with the measured tomato volume and hence with its weight.

P4-perceived aroma/smell of the tomato could only be related to the moisture contents. With these laboratory measurements perceived aroma could not be explained satisfactorily. R^2 was not significant.

P5-inner appearance perceptions, the most important dimension, can be improved significantly by a full red color of flesh and a thick fruit wall. It is further enhanced by reduction of the number of loculi and the severity of visible damages.

P6-perceived amount of pits and gel can be influenced by the amount of pits and gel measured by the mini-panel. It should be noted, that despite being significant at p<.001, R^2 is relatively low, 10%. This is could be due to inaccuracies of measurement. Another reason could be, that neither absolute core length nor relative core length (length as a percentage of the distance between stem and corona) could be related to this dimension.

P7-typical tomato taste (tasteful, aromatic, crispy, not tart) can be made stronger by an improved red color, by a thicker fruit wall and by high values of sugar*acid. Reduction of the severity of visible damages also improves the taste.
Total soluble solids dropped out of the equation, because of the high correlation with sugar*acid (r=0.60, p<.001). It must be noted, that all beta-values are relatively low (p<.10) and consequently R^2 is only 11%. This is probably due to the fact, that the aromatic component has not been measured.

P9-perceived sweetness/not sourness could only be explained for 16%. It is improved by a high sugar/acid ratio, a high pH, high solids contents. Even after having adjusted for sugar/acid ratio, ripeness improved the taste, and hence the quality of fruit tomato.

It should be noted, that sugar contents should be as high as possible (within the ranges measured, i.e. 0.4-3.1%). But acidity has an optimum: to achieve high values of sugar*acid, total titrable acids must be high, but to obtain high values of sugar/acid ratio, total titrable acids must low. However, a curvi-linear effect between acidity and taste quality could not be found. This is probably so, because the effect of acidity is greater in sugar/acid ratio than its effect in sugar*acid.

Classification of properties

Of the significant causal relationships above, the optimal level and the problem level were determined. Table 12 shows an example of how this quality classification was arrived at.

When sugar contents was higher than 1.6%, an aggregated majority of 68% of consumers considered the tomatoes sweeter than average and consequently of better quality. This is the optimal level. Sugar contents above 1.6% is therefore first class.

Tomatoes with a sugar contents below 1.1% were considered less sweet, hence worse than average by an aggregated 67% of consumers. The problem level is 1.1%. A tomato with less than 1.1% sugar is called third class. In between 1.1% and 1.6% a tomato may be referred to as second class.

Columns 7 and 13 are illustrative for problems due to small samples (see footnote number 5). The psycho-physical relationship is weakened by this irregularity ($r = 0.23$). However, it must be remembered, that the importance lies with the statistical significance of the relation. This significance was already tested in table 11 above ($p<.01$). We can therefore safely conclude, that the classification is valid, despite the irregularities.

The optimal fruit profile

In table 13 all classifications of relevant properties are given. Class boundaries did not always coincide. The optimal sugar contents for a typical tomato taste is 2%, for a sweet/not sour taste 1.6% is sufficient. Which level should be taken as optimal? The answer is 2%, because both will be first class. A similar note can be made for the problem level.

4. Quality problems

Table 14 shows a ranking of quality problems of perceptual dimensions and a ranking of product properties.

'Taiwan' tomatoes

Of the 'Taiwan' tomatoes researched 28% was considered too sour or insufficiently sweet. This could be explained by the fact, that 19% of the investigated 'Taiwan' tomatoes had a sugar/acid ratio less than 2.5. This was due to high acidity (over 0.6%), which occurred in 18% of the tomatoes, rather than to low sugar level (less than 1 percent), which was only encountered in 5% of all cases.

The second quality problem was that 22% of the tomatoes were considered to have a poor outer appearance (albeit being the best of the three varietal types researched). This could be related to the following class III properties: 24% had visible damages, 22% were of a yellow/orange color, 18% had a bleak flesh color and 16% were pink (not fully ripe).

The third problem, a lot of pits and gel (20%) was clearly due to a lot of locular gel (34%) and not to too many pits (6%).

The fourth problem was the weak smell/aroma of 20% of 'Taiwan' tomatoes. The only significantly related property, moisture level, was third class (over 96% moisture) in 10% of the tomatoes. As stated before, perceived smell/aroma could not be attributed further, because the tests carried out on aromatic substances were limited.

From this analysis the following priority list can be made:

To improve taste by:

* reduction of the acidity level, ultimately to 0.3%.

To improve the outer appearance by:

* reducing visible damages to zero, both pre- and post-harvest damages;
* enhancing red color of both skin and flesh to attain red value 9 on the CBT-scale.

To improve internal consistency by:

* reduction of locular gel to 'a little bit', which is considered optimal.

Highland tomatoes

According to consumers 43% of the Highland tomatoes surveyed, had many pits and a lot of locular gel, which is not liked when used for fruit. As with 'Taiwan' tomatoes this is primarily attributable to too much locular gel (33%) and not to too many pits (10%).

The second quality problem, related to the first one, was that 38% of Highland tomatoes looked unfresh and soft. This corresponded very well to manually felt firmness, measured in the laboratory: 38% was class III (soft-very soft). This lack of firmness could be related to a lot of locular gel (33%), a thin fruit wall (21%) and to high penetration (19%).

Aroma/smell was considered weak for 26% of Highland tomatoes. Like in the case of 'Taiwan' tomatoes, this problem could not be related to laboratory parameters, since only 5% of the Highland tomatoes had a high moisture contents.

From this analysis the following priority list can be made:

To increase firmness by:

* reducing locular gel to 'a little bit', which is considered optimal.
* increasing thickness of fruit wall, to over 6 mm, which is optimal;

Lowland tomatoes

Perceived sweetness is the most hampering factor for Lowland tomato quality: 69% of consumers experienced it as sour, insufficiently sweet. This was due to a low sugar/acid ratio (86% of investigated tomatoes!), which was affected by both high acidity (51%) and low sugars (46%).

The second problem was poor inner appearance (41%). This could be related to a thin fruit wall (54%), bleak flesh color (41%) and many loculi (37%).

The third problem was poor outer appearance (40%), due to their oblate shape (58%), visible damages (37%), yellow/orange/pink color (39%) and insufficient ripeness (39%).

From this analysis the following priority list can be made:

To improve taste by:

* increasing sugar/acid ratio by both reducing acidity and increasing sugar contents;
* harvesting tomatoes when they are fully mature.

To improve inner appearance by:

* enlarging thickness of fruit wall;
* enhancing red color of flesh to full red;
* reduction of the number of loculi;
* minimizing visible damages, both pre- and post-harvest damages.

To improve outer appearance by:

* enhancing red color of skin to full red;
* creating a round tomato.

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Table 1a - External Sensory Attributes and Corresponding Laboratory Analyses

Sensory Perception		Laboratory Analysis	
I External	description	measurement	range
A Appearance of tomato			
1 general appearance	good-bad	physical damage	0 - 3
2 ripeness	ripe-unripe	ripeness class	30-100% red
3 freshness	fresh-unfresh	days after harvest	0 - 5 days
4 description of color	nice-not nice	CBT color chart	3 - 12
5 evenness of color	even-uneven	green shoulder	no - yes
		sunscalding	no - yes
6 shape	nice-not nice	LEHRI shape chart	1 - 14
		sphericity index	60 - 175
		number of ribs	0 - 10
7 size	small-big	volume	30 - 250 cm3
8 gloss	glossy-dull	intensity of gloss	1 - 5
B Texture of tomato			
9 firmness	soft-hard	manual feel	1 - 5
10 skin smoothness	smooth-coarse	not measured	
C Odor (smell)			
11 strength typical odor	strong-weak	not measured	
12 strength smell of rot	strong-weak	not measured	

Note: CBT = Central Bureau for Auctions of Horticultural Products in Holland.

Table 1b - Internal sensory properties and laboratory analyses

Sensory Perception		Laboratory Analysis	
II Internal Properties			range
D Appearance inner part			
13 general appearance	orderly-messy	number of loculi	2 - 10
14 color of flesh	nice-not nice	LEHRI color chart	1 - 9
15 quantity of flesh	little-much	thickness of wall	1 - 12 mm
16 quantity of pits	few-many	visible pits	1 - 3
17 qty of locular gel	little-much	visible locular gel	1 - 3
18 length of core	short-long	length of core	2 - 45 mm
		%core length/height	1 - 100%
E Texture inner part			
19 firmness of flesh	soft-firm	penetrometer	10 - 350 mm/ 50g/10sec
F Odor (smell) tomato			
20 strength of aroma	strong-weak	not measured	

Table 1c - Organoleptic properties of tomato

II Organoleptic Properties			range
G Flavour/Aromas			
21 typical tomato taste	strong-weak	not measured	
22 tastefulness	strong-weak	total soluble solid	3.1% - 6.8%
		sugar*acid*	0.6 - 3.0
23 sweetness	sweet-not sw.	glucose+fructose	0.4% - 3.1%
24 sourness	sour-not sour	total titrable acid	0.20 - 0.80
		pH	3.70 - 4.86
25 tartness	tart-not tart	sugar/acid ratio	0.58 - 8.00
H Texture/Consistency			
26 crispiness of flesh	crispy-mealy	not measured	
27 rubbery skin	tough-soft	not measured	
28 juiciness	juicy-dry	moisture contents	92% - 96%

* sugar*acid = square root (sugar contents^2 + acid contents^2)

Table 2 - Some characteristics of three types of tomatoes in Indonesia

tomato type	market share	price	weight	description
1. 'Taiwan' varieties	50%	Rp 1,000/kg	70gr	firm, oval to round, well keepable
2. Highland varieties	30%	Rp 800/kg	80gr	juicy, oval to oblate, sweet
3. Lowland varieties	20%	Rp 500/kg	40gr	soft, pale, oblate, hard skin, sour

Table 3 - Factor matrix for external sensory tomato aspects after Varimax rotation (n=200)

FACTOR NAME:	OUTER APPEARANCE	FIRM/ FRESH	SIZE	AROMA
ripe	.78	.18	-.09	.05
nice color	.67	.34	-.14	.21
even coloring	.65	.20	-.12	-.06
nice appearance	.50	.36	.05	.30
nice shape	.46	.24	-.12	.56
smooth skin	.44	.52	-.14	.05
firm	.13	.74	-.30	.08
fresh	.25	.64	-.23	.22
gloss	.29	.60	.04	.08
no smell of rot	-.01	.56	.22	.03
small size	-.14	-.04	.80	.04
strong aroma	-.09	.03	.08	.87
cumulative variance	30%	40%	48%	56%

Table 4 Factor matrix for internal sensory tomato aspects after Varimax rotation (n=200)

FACTOR NAME:	INNER APPEARANCE	PITS/ GEL
orderly inner appearance	.87	.12
nice color of flesh	.82	-.05
strong aroma	.76	-.22
much flesh	.60	.30
few pits	.14	.76
no locular gel	-.05	.69
short core	-.04	.46
firm flesh	.27	.30
cumulative variance	31%	49%

Table 5 Factor matrix for organoleptic tomato aspects after Varimax rotation (n=200)

FACTOR NAME:	TYPICAL TOMATO TASTE	JUICY/ NO TOUGH SKIN	SWEET/ NOT SOUR
tasteful	.77	.10	.05
aromatic flavor	.63	.14	-.07
crispy flesh	.52	-.08	.19
tart	-.51	.11	-.21
juicy	-.00	.77	-.15
tough skin	.03	-.76	-.08
sweet	.37	-.09	.70
sour	.08	.07	-.89
cumulative variance	23%	40%	53%

Table 6 Single correlations (r) and beta-values (ß) between expected quality of tomato and cognitive and external sensory factors - the underlined word indicates the preferred direction.(n=200, $p<0.05$)

External Sensory Dimension	r	ß
outer appearance (nice/not nice)	0.40	0.39
fresh/firmness (fresh/firm/unfresh/soft)	0.37	0.30
aroma (strong/weak)	0.26	0.23
size (big/small	0.22	0.22
Cognitive Aspect		
healthiness (healthy/unwholesome)	0.34	0.08 (ns)
multi-vitamins (a lot/little)	0.24	0.07 (ns)
shelf life (long/short)	-0.16	-0.12
ease of use (difficult/easy)	0.02 (ns)	0.03 (ns)

Table 7 Single correlations (r) and beta-values (ß) between experienced quality of tomato and external, internal and organoleptic dimensions - the underlined word indicates the preferred direction (n=200, p<0.05)

	r	ß
External Sensory Dimension		
fresh-firmness (fresh-firm/unfresh-soft)	0.42	0.13
outer appearance (nice/not nice)	0.33	0.17
aroma (strong/weak)	0.26	0.15
size (big/small)	0.25	0.15
Internal Sensory Dimension		
inner appearance (nice/not nice)	0.68	0.35
amount of pits-gel (little/much)	0.21	0.17
Organoleptic Dimension		
sweet-not sour (sweet-not sour/not sweet-sour)	0.47	0.22
typical tomato taste (strong/weak)	0.42	0.09 (ns)
juice-skin (juicy-not tough/dry-tough)	-0.07 (ns)	-0.06 (ns)

Table 8 Expected and experienced quality of tomato varieties used for fruit in Indonesian towns; 1=very good, 3=reasonable, 6=very bad (n=200)

variety	average expected quality	average experienced quality	difference expected-experienced quality
'Taiwan' varieties	2.56 a	2.86 a	-0.30 (p=.09)
Highland local varieties	3.21 b	3.17 a	0.04 (n.s.)
Lowland local varieties	5.12 c	5.14 b	0.02 (n.s.)
All varieties supplied	3.28	3.42	-0.14 (n.s.)

note: different letters indicate significantly different means between varieties (LSD-test; p<0.05)

Table 9 Perceptual differences between three types of tomato varieties in Indonesia. Figures indicate preferred ranking according to the consumer. Equal figures indicate no perceptual difference existed between the types (n=200, p<.05)

	P1 better outer app.	P2 firmer fresher	P3 bigger size	P4 stronger aroma	P5 better inner app.	P6 less pits & gel	P7 stronger taste	P9 sweeter less sour	C1 healthy	C2 well keepable*	C3 more vitamin
'Taiwan'	1	1	1	1	1	1	1	1	1	1	2
Highland	1	2	1	1,2	1	2	1	1	1	2	1

Lowland	2	2	2	2	2	2	2	2	2	1,2	2

* significant at p<.10

Table 10 Significant single correlations between product properties and perceptual dimensions. Causal relationships are underlined. Properties with more than one causal relationship are marked with an asterisk. (n=200, p<.10)

	P1 better outer app.	P2 firmer/ fresher	P3 bigger size	P4 stronger aroma	P5 better inner app.	P6 less pits & gel	P7 stronger taste	P9 sweeter/ less sour	C1 healthy	C2 well keepable	C3 more vitamin
EXTERNAL											
* 1 volume	0.16		0.70		0.34		0.19				
* 2 sphericity	-0.22	-0.33			-0.38	-0.16	-0.16	-0.36	0.21		
3 color of skin	0.58				0.31		0.18	0.20			0.24
* 4 ripeness	0.54				0.32		0.22	0.14	0.15		0.19
5 ribs	-0.14								0.18		
* 6 visible damages	-0.16				-0.17		-0.18			-0.22	
* 7 firmness manual	-0.23	0.50	0.23		0.22	0.29		0.24	0.26	0.26	
8 green shoulder		0.24			0.19	0.12		0.17			
INTERNAL											
* 10 color flesh	0.55				0.38		0.22	0.25	0.20		0.22
* 11 wall thickness	0.20	0.23	0.29		0.38	0.14	0.19	0.32	0.26		0.15
* 12 loculi	-0.14	-0.27		-0.16	-0.23	-0.18	-0.14	-0.39	0.15	-0.12	
13 penetration	0.39	-0.38				-0.24				-0.15	
* 14 pits		-0.23				-0.24		-0.22			
15 locular gel		-0.19	0.19			-0.14	-0.12			-0.19	
16 core length	0.16	0.13			-0.22		0.23	0.20	0.23	-0.21	
CHEMICAL											
* 17 sugar%	0.14	0.18			0.31		0.23	0.23	0.17		
18 sugar/acid		0.21			0.25	0.13	0.19	0.28	0.19		
19 acid%		-0.15			-0.18	-0.17		-0.24	-0.19	-0.19	
20 pH					0.14			0.26			
* 21 soluble solids					0.12		0.14	0.19			
22 sugar*acid	0.13	0.15			0.26		0.21	0.18			
23 moisture%	0.18			-0.18						0.16	

Table 11 Significant beta-values and R^2. Perceptual dimensions regressed on properties with causal relationships (n=200, p<.10)

	P1 better outer app.	P2 firmer/ fresher	P3 bigger size	P4 stronger aroma	P5 better inner app.	P6 less pits & gel	P7 stronger taste	P9 sweeter/ less sour
EXTERNAL								
1 volume			0.70***					
2 sphericity	-0.14*							
spheri-quadratic	0.15**							
3 color of skin	0.37***							
4 ripeness								0.14*
6 visible damages	-0.12*				-0.14*		-0.14*	
8 green shoulder		0.13*						
INTERNAL								
10 color flesh	0.24**				0.26***		0.14*	
11 wall thickness		0.16**			0.26***		0.11*	
12 loculi					-0.11*			
13 penetration		-0.30***						
14 pits		-0.19**				-0.29***		
15 locular gel		-0.13*				-0.21**		
CHEMICAL								
18 sugar/acid ratio								0.22**
20 pH								0.23**
21 soluble solids								0.13*
22 sugar*acid							0.13*	
23 moisture%				-0.18*				
R^2	40%***	24%***	49%***	3%	34%***	10%***	11%***	16%***

Note: a significant quadratic effect means that the relationship is curvi-linear, not linear
*** p<.001 ** p<.01 * p<.10

Table 12 Percentage of consumers considering the TASTE of tomato SWEETER and LESS SWEET than average and corresponding levels of SUGAR CONTENTS measured by the percentage of glucose + fructose.

	SUGAR CONTENTS %													
	0.40 0.69	0.70 0.99	1.00 1.09	1.10 1.19	1.20 1.29	1.30 1.39	1.40 1.49	1.50 1.59	1.60 1.69	1.70 1.79	1.80 1.89	1.90 2.19	2.20 3.49	Total
SWEETER TASTE	4	6	7	8	7	1	7	8	12	11	9	7	14	99
	26.7%	33.3%	36.8%	50.0%	46.7%	8.3%	43.8%	57.1%	83.3%	73.3%	69.2%	42.8%	73.6%	
LESS SWEET TASTE	11	12	12	8	8	11	9	6	2	4	4	9	5	101
	73.3%	66.7%	63.2%	50.0%	53.3%	91.7%	56.2%	42.9%	16.7%	26.7%	30.8%	57.2%	26.4%	
Number of Consumers	15	18	19	16	15	12	16	14	12	15	13	16	19	200

Table 13 Classification of tomato properties according to consumer perceptions of relevant sensory dimensions and cognitive factors
The properties marked with an asterisk are used to compose the optimal fruit profile.

	optimal level	problem level		optimal level	problem level
P1 - OUTER APPEARANCE			P5 - INNER APPEARANCE		
* color (CBT-chart)	≥9	≤5	* color of flesh (LEHRI-chart)	≥6	≤3
* color of flesh (LEHRI-chart)	≥6	≤3	* thickness fruit wall (mm)	≥6mm	≤2mm
* sphericity index	90-120	≥120	* number of loculi	2-3	≥7
* visible damages	0	≥2	* visible damages	0	≥3
* number of ribs	n.a.	≥9	P6 - AMOUNT OF PITS & GEL		
P2 - FRESH/FIRMNESS			* visible pits	≤2	≥3
* firmness manual	≥4	≤2	* locular gel	1	n.a.
* penetration (mm/50g/10sec)	≤100	≥160	P7 - TYPICAL TOMATO TASTE		
* green shoulder	yes	n.a.	* sugar*acid intensity	n.a.	n.a.
thickness fruit wall (mm)	≥6mm	n.a.	* glucose + fructose contents	≥2%	≤1%
visible pits	n.a.	≥3	* total titrable acids	n.a.	n.a.
locular gel	n.a.	3	color of flesh (LEHRI-chart)	≥7	≤3
P3 - SIZE			thickness fruit wall (mm)	n.a.	≤3mm
* volume (cm3)	≥100	≤40	visible damages	0	≥2.5
P4 - AROMA			P9 - SWEET/NOT SOUR		
* moisture contents	≤94%	≥96%	* sugar/acid ratio	≥4.5	≤2.5
			* glucose + fructose contents	≥1.6%	<1.1%
Note: n.a. means that no 60% majority of consumers existed, who liked or disliked tomato at any level of that property.			* total titrable acids	≤0.3%	≥0.6%
			* pH	≥4.2	<4.0
			* total soluble solid contents	≥4.6	≤3.6

Table 14a Ranking of perceptual dimensions of three tomato types, according to the percentage of tomatoes considered to be of "poor" or "very poor" quality when experienced for fruit.

'Taiwan'	n=99	Highland	n=42	Lowland	n=59
poor experienced quality	28%	poor experienced quality	33%	poor experienced quality	90%
1 not sweet/ too sour	28%	1 a lot of pits and gel	43%	1 not sweet/ too sour	69%
2 poor outer appearance	22%	2 unfresh/soft	38%	2 poor inner appearance	44%
3 a lot of pits and gel	20%	3 weak aroma/smell	26%	3 poor outer appearance	41%
4 weak aroma/smell	20%	4 poor inner appearance	14%	4 insipid taste	36%
5 small size	16%	5 poor outer appearance	12%	5 weak smell/aroma	31%
6 insipid taste	11%	6 not sweet/ too sour	12%	6 small size	27%
7 poor inner appearance	6%	7 insipid taste	10%	7 a lot of pits/ gel	21%
8 unfresh/soft	1%	8 small size	10%	8 unfresh/soft	17%

Table 14b Ranking of product properties of three tomato types, according to the percentage in class III.

'Taiwan'	n=99	Highland	n=42	Lowland	n=59
1 a lot of locular gel	34%	1 unfirm manually	38%	1 low sugar/acid ratio	86%
2 many visible damages	24%	2 a lot of locular gel	33%	2 unfirm manually	61%
3 yellow/orange color	22%	3 many visible damages	24%	3 oblate shape	58%
4 low sugar/acid ratio	19%	4 thin fruit wall	21%	4 thin fruit wall	54%
5 bleak color of flesh	18%	5 high penetration	19%	5 high titrable acidity	51%
6 low soluble solids	18%	6 low pH	14%	6 low glucose+fructose	46%
7 high titrable acidity	18%	7 bleak color of flesh	14%	7 bleak color of flesh	41%
8 not fully mature	16%	8 yellow/orange color	14%	8 yellow/orange color	39%
9 low pH	14%	9 low soluble solids	14%	9 not fully mature	39%
10 small	14%	10 low sugar/acid ratio	12%	10 many visible damages	37%
11 high moisture contents	10%	11 small	10%	11 many loculi	37%
12 unfirm manually	9%	12 many pits	10%	12 low pH	36%
13 thin fruit wall	6%	13 oblate shape	10%	13 small	34%
14 high penetration	6%	14 high moisture contents	5%	14 many pits	24%
15 many pits	6%	15 low glucose+fructose	5%	15 low soluble solids	20%
16 low glucose+fructose	5%	16 not fully mature	5%	16 high penetration	17%
17 oblate shape	4%	17 high titrable acidity	0%	17 high moisture contents	10%
18 many loculi	3%	18 manu loculi	0%	18 a lot of locular gel	5%