DEFINITION AND MEASUREMENT OF MEAT QUALITY

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INTRODUCTION: In the area of meat production and meat science there is hardly a topic which has gained such an importance in the last few years as the term "quality".
On the other hand we must acknowledge that there is hardly another term being connected with so many different conceptions.
Therefore "quality" is very often used in a different sense and with different meanings which lead to a lack of consense or even to confusion. This situation is extremely unsatisfactory and needs to be clarified.
Somebody may wonder to see that the definition of meat quality is placed into the analytical session at this congress. However, it has to be stressed that meat quality as we will see it is indeed a matter of analytical measurements. Of course in the latter not only those methods are included which are well known in the classical chemical analysis but all methods available, giving us objective information about the subject "meat" in the widest sense.

HISTORICAL APPROACHES: One of the best known and most quoted definitions of quality in connection with meat was given by Hammond (1955): "Quality can best be defined as that which public likes best and for which they are prepared to pay more than avarage prices".
I will show you later in this presentation that this interpretation which takes only the aspects of profit into the consideration cannot be accepted for scientific purposes. It concerns the "degree of goodness" rather than the objective characterization of quality.
Jul (1973) pointed out "that the concept of quality varies from area to area and between population groups". Therefore he stressed that quality "is not a matter of characteristics deduced from laboratory findings", and "no uniformly accepted or acceptable definition of quality exists, and in fact, could not exist". Steinhauf (1970/71) stated, that the use of the term "quality" leads to difficulties with respect to animal production and suggested instead of quality to use the term "record", because records were biological measurable values, which influence the economic result of animal production.
Whatsoever, it is obvious, that each material, no matter whether it is a carcase, meat or meat product, is characterized by distinctive properties, which of course could be used to formulate a definition of quality. According to this Scheper (1962) established that the idea of meat quality, if analyzed, is composed of a number of factors like proteins, fat, water, color, tenderness, taste and others. This point of few seemed to be a valuable approach for an objective definition of meat quality.
However, Prändl (1973) concluded in general that although many attempts were made to define meat quality, there was no success in finding a definition which could be universally valid and acceptable with respect to different interests.
These difficulties and the contrary opinions shown above may be reduced to the fact, that the word "quality" may have different meanings. This should be analyzed in connection with meat in the following section.

GENERAL REFLECTIONS ON QUALITY: In the colloquial speech the word "quality" is so common, that normally there seems to be no necessity to define what it really means. But as we have seen above in connection with meat and with respect to its importance as a food for the human being a clear definition is needed. Of course such a definition should be valid not only for meat ready to eat, but in a broader sense also for the carcase and for meat as a raw material for meat products. There is a real ambiguity in the way in which the word "quality" is used and thought about.
In dictionaries usually two different meanings of "quality" are given (e.g. Kinsman, 1978):

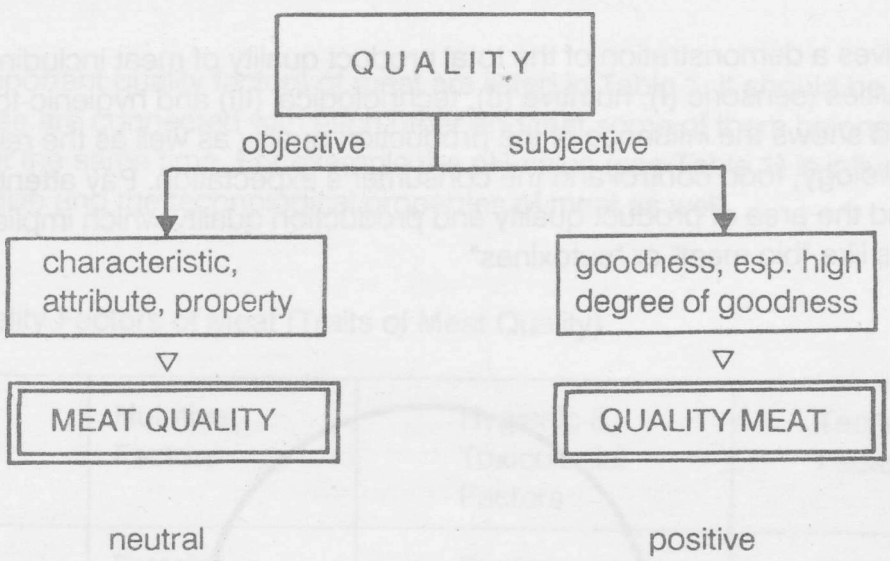
1. distinctive property, characteristic or attribute (according to the Latin "qualitas");
2. measure of goodness, fineness or excellence; grade.

The first interpretation is objective. It is related to the material properties which can be described and measured objectively. The second application is subjective, depending on the opinion and the appreciation of the consumer (the properties of a product are of course independent from the latter). It is quite obvious that an objective and in general acceptable definition of quality has to be based on the special properties and characteristics of a product and it has to be free as far as possible from any subjective evaluation. This is not easy to be fullfilled, but necessary.

The whole dimension of the difficulties should be illustrated by the following example regarding food quality and quality control: "Quality may be defined as the totality of features and characteristics of a product that bear on its ability to satisfy a given need" (EOQC, 1976). Although this definition is probably widely recognized it suffers on its implication from one objective and one subjective part: The objective part concerns the "features and characteristics", and the second part concerns the "given need". Naturally the latter differ from consumer to consumer and depend widely from their subjective wishes and appreciation.
In the author's opinion it would be more correct to formulate the second part of the cited definition as follows:"... characteristics of a product being important for its function as a food". This "function" depends from the properties of the special product, so that the definition in this form is made objective also in the second part.

From the said above it is quite obvious that an objective definition of meat quality has to be independent of a good-bad evaluation. This of course does not mean that the subjective appreciation of the consumer would be ignored. Objective and subjective or neutral and valuating aspects are without doubt both of great importance, but at the moment they have to be disconnected from each other and to be discussed separately. In order to distinguish clearly the objective from the subjective interpretation of "quality" it is suggested to use the term "quality meat" for the latter.
More about "quality meat" will be given later in a separate section.

The result of these considerations may be illustrated by the following scheme:



DEFINITION OF MEAT QUALITY: An objective characterization or definition of "meat quality" being independent from any evaluation can be achieved on the basis of the composition and the properties of the meat, which in principle can be measured and described by objective methods.

For further consideration it will be advantageous to use the integrating expression "quality factors" instead of the different expressions like "properties", "characteristics", "attributes", "features" or "traits" which are usually used in conncetion with quality.

Meat is not only a complex mixture of many constituents and compounds but a very complicated micro- and macro-structured tissue. Its properties are influenced by numerous factors ante and post mortem (review see Scheper, 1962 and Jeremiah, 1978). In order to prevent an interfering with the "quality factors" it is suggested to call them "influencing factors". All the quality factors of meat may be divided into four groups according to their importance for the (1) epicurean, (2) the nutritive, (3) the hygienic (including toxicological) and (4) the technological value:

1. Sensoric factors
2. Nutritive factors
3. Hygienic and toxicological factors
4. Technological factors

All potential quality factors may be directed into one of these four categories, so that there is no need for establishing other or additional categories. The quality of meat is a complex of all of its properties and traits. Therefore it can be defined (Hofmann 1973,1974,1987):

Meat quality is the sum of all sensory, nutritive, hygienic-toxicological and technological properties of the meat.

Or substituting the latter by the term "factors" we can say more briefly:

Meat quality is the sum of all quality factors of meat

Each of these quality factors may be measured and characterized objectively; even sensoric analysis if carried out correctly can be regarded to be objective. In most cases not the total quality of the meat will be of interest but rather different scopes of it.

Figure 1 gives a demonstration of the total product quality of meat including the different partial qualities (sensoric (I), nutritive (II), technological (III) and hygienic-toxikological (IV) quality) and shows the influence of the production quality as well as the relevant areas for meat technology, food control and the consumer's expectation. Pay attention on the section beyond the area of product quality and production quality which implies imaginations and fictions like "bio meat" or "sutoxines"

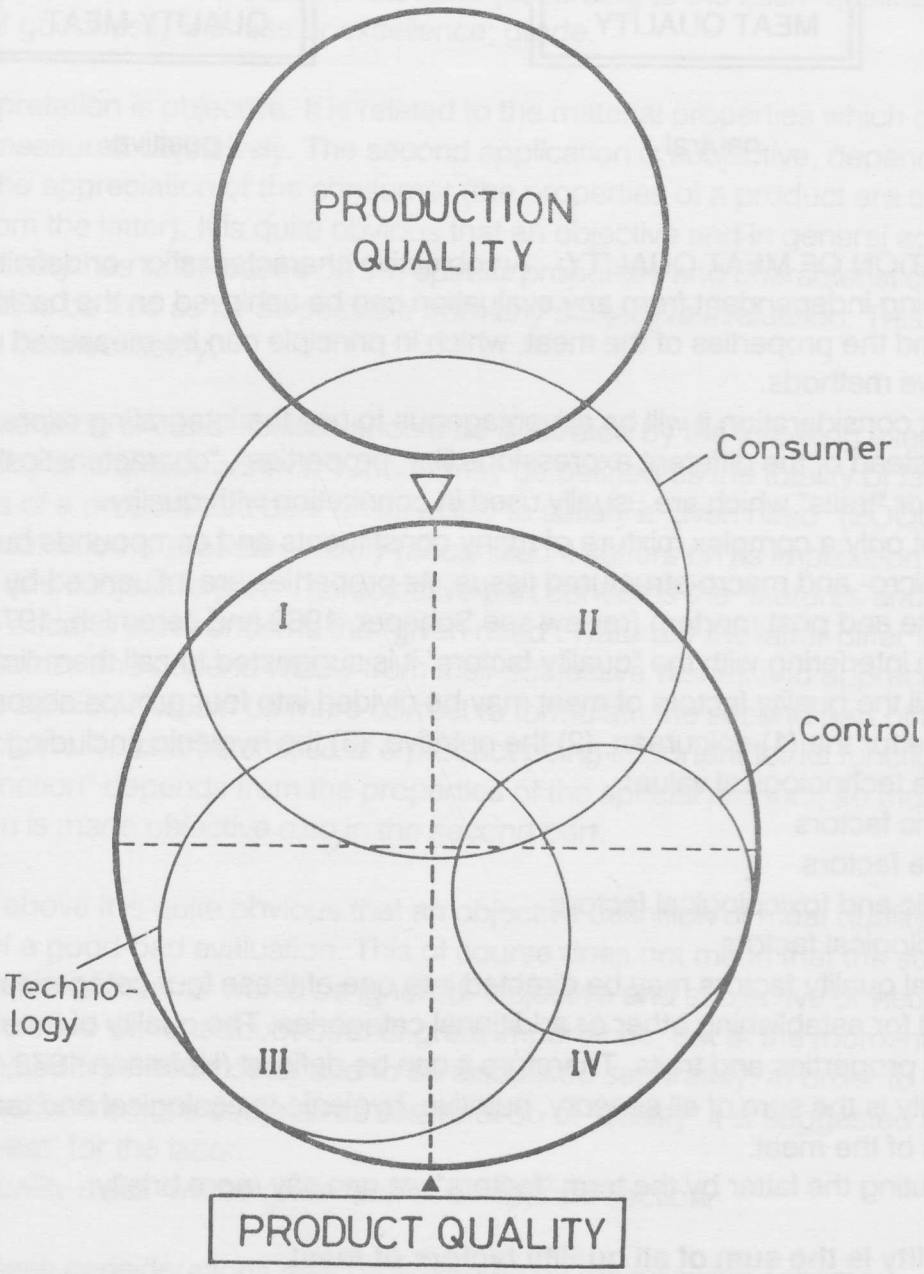


Figure 1: The influence of the production quality on the product quality and their different relevance for meat technology, food control and the consumer's expectation

The most important quality factors of meat are listed in Table 1. It should be mentioned that many of these are connected with each other and that some of them belong to different categories at the same time. For example the pH-value (see Table 1) is influencing the taste, the shelflife and the technological properties of meat as well.

Table 1: Quality Factors of Meat (Traits of Meat Quality)

Sensoric Factors	Nutritive Factors	Hygienic & Toxicologial Factors	Technological Factors
Color	Proteins	Bacteria	Structure
Shape	BEFFE	Spores	Texture
Marbling	Amino Acids	Moulds	Consistency
Smell	Fatty Acids	Shelflife	Viscosity
Taste	Vitamines	pH-value	Color
Flavour	Minerales	Water activity	Water binding
Fat content	Utilization	(a_W-value)	capacity (WHC)
Fat composition	Digestibility	Redoxpotential	Water content
Tenderness	Biological value	Nitrite	State of proteins
Texture		Nitrate	State of fat
Juiciness		Toxines	Connective tissue
pH-value		Residues	pH-value

In the past considerable confusion has arisen over the understanding of the term "meat quality", because the objective aspects have been mixed with the consumer's appreciation which is of course subjective by nature. Therefore these subjective aspects have to be distinguished strictly from the objective quality. They are two different sides of the one coin. Related to "appreciation" are the terms acceptibility, preference, usefulness, profit, social value etc.; they do not primarily exist like the quality factors, but they are the result of them. A third aspect in this connection is the price as shown in Fig. 2. The price of a product depends on several influences first of all from the relation of supply and demand, whereby the demand is effected decisively by the appreciation or preference of the customer. Therefore the price does not reflect the quality of a product directly (see Fig. 2).

If the quality of meat is considered according to our definition without subjective evaluation, meat with PSE and DFD properties may be regarded from the standpoint of the consumer as "poor quality" but not in general as "bad" meat quality because this meat is quite useful for meat processing to produce sausage, ham and other products. Therefore the quality of meat should be assigned objectively as "useful" or "less useful" in regard to its special purpose of application (review see Hofmann, 1988). In Fig. 2 the different relations between

the objective term quality, the subjective term appreciation, the price and the different influences on it are presented graphically.

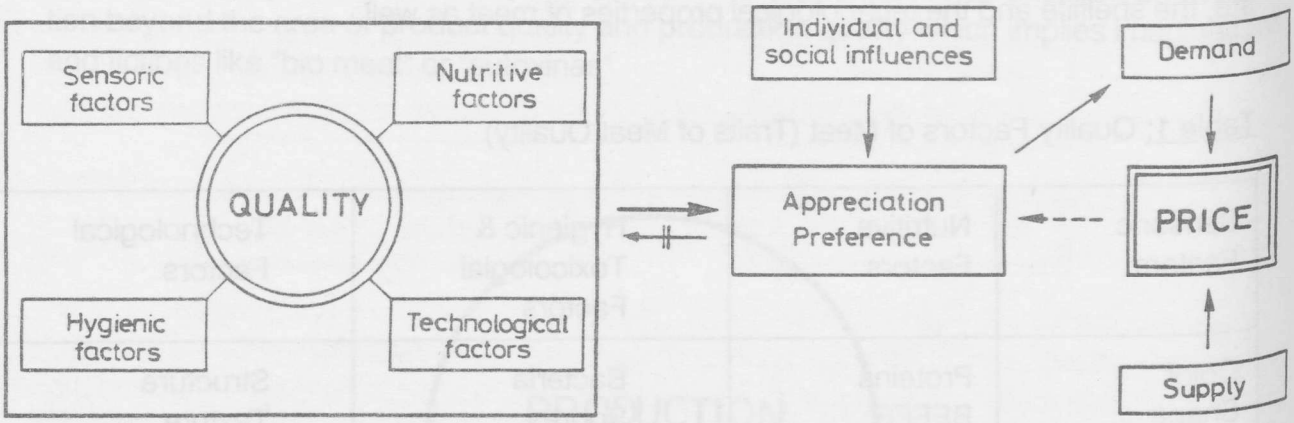


Figure 2: Relation between product quality, given by the measurable quality factors, the subjective appreciation or preference and the price of a product. The direction of influences is marked by the arrows

After this discussion it is quite clear that Hammond's definition of "quality" (see HISTORICAL APPROACHES) is not able to be related to "meat quality" but to "quality meat". Also the difficulties in the definition of quality as expressed by Jul, Steinhauf and Prändl can be understood now, because "quality meat" cannot be defined exactly but only characterized by several criterions (see Table 5) which depend on the subjective appreciation and preference of the customer.

METHODS OF QUALITY MEASUREMENT AND ASSESSMENT: We have seen that "meat quality" is in contrast to "quality meat" not a matter of subjective meanings but of objective measurements.
Besides the methods of chemical analyses and physical measurements the sensory analysis of meat and meat products has been developed to an important tool for their objective evaluation. The organs of senses of the human being may be considered as "biological measuring instruments", and the sensory analysis has to be distinguished from organoleptic tests. The difference between both methods is to be seen in the different level of knowledge and qualification of the taste panel. Organoleptic testers are persons with no training in sensory analysis, confusing quality tests with hedonic evaluations, whereas the sensory analyst is working like an instrument (Jellinek, 1981). Thus sensory analysis is the science of evaluating food products by the human sense of sight, taste, smell and touch. They are used successfully in quality and processing control and in food science.

The hygienic status of meat and meat products is also an important part of quality assessment which includes the investigation of micro-organisms, toxins and residues (heavy metals, antibiotics, pesticides, hormones etc.).

In order to characterize the "partial quality" of a product corresponding to the four groups of quality factors the expressions "sensory quality", "nutritive quality" etc. may be used. Methods for the objective measurement of the different quality factors are listed in Table 2.

Table 2: Quality factors of meat and their determination

Factor	Subject of Measurement	Method/Device (examples)
- Sensory Factors -		
Color	Color and brightness	Göfo
	Components of color	Hunterlab etc.
Shape, Size	Area of cut	Planimeter
Firmness	Shear force	Warner Bratzler, Instron
Flavour	Flavour components	Gaschromatography, Mass spectrometry
- Nutritive Factors -		
Protein	Protein content,	Kjeldahl
	Kind of protein	Electrophoresis
Connective tissue	Hydroxyprolin	Colorimeter
Fat	Fat content	Soxhlett
Minerals	Ash	Combustion apparatus, Atom absorption
Vitamines	Vitamine content	Calorimetry, Chromatography
- Hygienic Factors -		
pH-value	pH-value	pH-Meter
Shelf life	Microorganisms	Plate count
Residues	e.g. Heavy metals	Atom absorption
- Technological Factors -		
Water binding capacity	Drip/Cooking loss,	Volume/Weigth
	Juice pressed out,	Filter paper press and centrifugation method
	Juice sucked out	Kapillarvolumeter
Fat	Consistency	Melting point
Viscosity	Emulsion	Viscosimeter

One of the most important quality factors of meat is undoubtedly the water holding (or binding) capacity (WHC). A decrease of the WHC is connected with the following disadvantages (Kauffman et al., 1986):

1. Weight loss during storage, transit and display
2. Unattractive retail packages
3. Decreased yield and quality of processed products
4. Decreased juiciness
5. Decreased tenderness and texture
6. Loss of nutritients (together with the drip)

Because of the importance of the WHC of meat its measurement should be commented briefly. Many different methods, based on different principles, have been developed (see Hamm, 1972). However, their applicability depends on the aim of investigation. To determine the WHC of fresh meat those methods are most suitable, which do not destroy the tissue or denature the proteins (e.g. drip and suction methods).

For heated meat the cooking loss is suggested and in the case of processed meat corresponding samples should be prepared (Honikel, 1986).

We do not intend to consider the methods for the determination of the quantitative composition of meat. These are important for the food inspection system and should not be discussed here. However, methods for the estimation of PSE and DFD defects and other deficiencies which are effecting the consumer's appreciation are of great importance in our considerations about meat quality.

In the last few years great efforts have been made in order to improve the meat quality, especially of pork. Therefore "quality meat programms" were created, in which on all steps of the meat production the quality of the material is systematically controlled. Methods available for this purpose are listed in Table 3.

Furthermore there is a series of factors influencing the meat quality (see Table 4), which have to be respected or which can be utilized for the strategy of quality improvement.

EVALUATION OF MEAT QUALITY: The quality factors of meat are of course not able to be considered as independent from each other. Therefore meat quality, which is a complex of many different properties, can hardly be represented by a single score. The more factors are included into the evaluation the more reliable the conclusions will be. However, in practice compromises have to be made between accuracy and economy.

Table 3: Potential methods for quality assessment at different steps of meat production and processing

Production line	Method resp. Measurement
Animal	Halothane test Creatine kinase test Biopsy test Ultrasonics Infrared thermography Computer tomography
Carcase	pH value Conductivity (LF value) Impedance Color and brigthness (visual) Reflection (Göfo, Hunterlab) Optical probe (on-line methods) Muscle and fat layer (slide caliber) Computer tomography Biosensors
Meat	Eating quality Epicurian value pH-value LF value Color coordinates ($L^*a^*b^*$) Göfo/Hunterlab Transmission Pigment content Water holding capacity R-value (relation ATP/IMP) Rigor value Sarcomere length Tenderness (shear force) Marbling (visual, photograph) Chemical analysis Microbiological investigations
Meat product	Chemical analysis Infrared measurement (fat content) Sensory analysis Electrophoresis (foreign protein/species) pH-value Water activity (a_w-value) Viscosity (emulsion stability) Residues (AA,GC,HPLC,MS,NMR, enzymatic test, ELISA) Microbiological investigations

Table 4: Factors effecting meat quality

Genera Species Breed Sex Husbandry Feeding regime Influence of stress Kind of muscle, cut Carcase weigth Fatness/Marbling Chronological age Physiological maturity	Physiological and physical factors
Post mortem changes Conditioning Chilling Freezing Packaging Cooking Processing	Postmortem handling and treatment
Electrical stimulation Carcase tensioning Ageing Chilling Mechanical tenderization (Tumbling) Tenderizers (proteases)	Technics for postmortem improvement of tenderness

In general the objective evaluation of meat quality is founded on the perception that we can imagine an optimum of quality, which may be called optimum state (OS). The quality measurements provide the data for the actual state (AS). Thus the deviation of quality (ΔQ) is given by the difference of both:

$$\Delta Q = OS - AS$$

The optimum-state of meat corresponds to "quality meat" the criterions of which are summarized in Table 5.

In principle the definition of meat quality could be also related to the carcase. However, when it is officially evaluated by the grading system (EUROP) only the percentage of lean meat is included. **What there is called "carcase quality" is consequently nothing else than the appreciation of quantity!**

Table 5: Criterions for "quality meat" (Note: "Uniformity" is often thought to be a crterion for quality, however, it is rather a criterion for a branded article)

High degree of tenderness High degree of juiceness Excellent flavour	PALATIBILITY
Low microbiological contamination Low in residues	SAFETY
Low in drip High water holding capacity Adequate color	ATTRACTIVITY

One of the most important quality indicators, for raw meat is the pH-value. The speed and extent of the drop in pH after slaughter has a particular influence on the sensory quality factors and the processing properties of the meat. If the pH drops very quickly the meat will be watery, pale, soft and of poor aroma and will bind badly (PSE quality). A very slow and incomplete drop in pH, however, means dark, dry (sticky) and firm meat that does not keep so well (DFD meat). Normal meat undergoes a moderate and complete drop in pH.

The measurement of the pH-value can therefore reveal the meat quality in a carcase. In the last years the measurement of conductivity (LF values) in meat has gained growing importance particularly as an uncomplicated one-line method.

pH and LF values typical for PSE and DFD defects as well as Göfo and drip values used as indicators for the meat quality are listed in Table 6. These values are based on the experiences of several authors and may be regarded as approximate guiding values. Conclusions drawn from them are more reliable if several values are combined together. In general the different methods for the quality measurement of meat can be divided into three groups corresponding to:

1. Raw meat (carcase, cut, minced meat)
2. Cooked meat (ready to eat)
3. Processed meat (meat products)

Table 6: Guiding values for marked meat quality deviations in pork and beef (after Scheper, 1980, Schmitten et al., 1984 and Kallweit, 1990)

Quality		Normal	PSE	DFD
Beef	pH_{24}	< 6.0		> 6.2
	LF_1	≤ 5.0		
	LF_{24}	≤ 8.0		
Pork	pH_1	> 6.0	< 5.8	
	pH_{24}	< 5.8		> 6.0
	LF_1	≤ 5.0	≥ 9.0	
	LF_{24}	< 8.0	≥ 10.5	
	$Göfo_{24}$	55 - 80	< 55	> 80
	$Drip_{24}$	< 3.5 %	> 4.5 %	

In the investigations of raw meat usually only instrumental measurements are relevant. Most of them are indirect methods (indicators) for the determination of the quality, first of all the drop of the pH value post mortem or the LF value.
For cooked meat sensory as well as instrumental methods are applied whereas for processed meat and meat products sensory analysis dominate.

In most cases for sensory tests special scales, adapted to the kind of material and the aim of investigation, are applied. Two instructive examples should be described: For sensory analysis of meat products an approved testing scheme is used since many years in the quality test of the DLG; the German agricultural society. For each product a special scheme is applied and different characteristics of the product are listed in a table. By means of a 5-point scale the testing criteria are scored and multiplied by a weighting factor (details see Sinell et al., 1983). The final result called "quality number" is given by the equation:

$$\text{Quality Number} = \frac{\text{Sum of weighted scores}}{\text{Sum of weighting factors}}$$

A system for the over-all evaluation of the raw material in the carcase has been suggested by Erdös et al. (1987). In this system the "effective value" of the raw material (carcase) is characterized by the properties of its components placed on a numerical scale estimated by an expert panel. These properties depend on the type of components, on their proportion, on their structure and on their size. The scale is related to an average carcase with a score of 100, and different carcases have a score which is different from 100. The panel scores are very close to the values expected from the properties of the components.

There are different ways to combine the different meat characteristics to an integrated quality number. Krüger and Schäfer (1988) introduced a new method for quality assessment of slaughter pigs based on a 20-point scale in which the quality deficiency corresponding to pH, drip loss and color brightness is expressed in form of vectors. After weighting them they are summarized forming a vector sum which is substracted from the maximum of 20 points. This system allows to recognice PSE and DFD tendencies or defects and gives an over-all quality number as well.

CONCLUSIONS:

1. The expression "quality" is ambiguous, it may mean character (property) or, quite different, goodness. This leads often to misunderstandings in discussions about meat quality.

2. It is suggested to use the word "quality" in the more definite combinations "meat quality" and "quality meat".

3. "Meat quality" may be defined objectively as the sum of the properties of meat. As this properties can be measured, meat quality can be measured.

4. "Quality meat" cannot be defined objectively because it depends on the customers appreciation. It may be characterized by "what people like best".

5. "Properties", "attributes", "characteristics" or "traits" may unequivocally be named "quality factors". These have to be distinguished from "influencing factors" which do not determine but effect meat quality.

6. The sum of the processes, treatments and influences during the production are suggested to be called "production quality". The influencing factors are important for the resulting meat quality but they are not a constituent part of the quality.

7. In principle "quality" can be applied on all steps in meat production: "Animal quality", carcase quality, meat cut quality, meat quality, meat product quality.

8. In the actual situation in which the carcase is evaluated only by its percentage of lean meat the so-called carcase quality is nothing else than the appreciation of the quantity.

9. Numerous methods and indicators are available for the control of the raw material, beginning with the slaughter animal up to the meat "ready to eat".

10. Sensory and instrumental analysis enable an objective evaluation of the quality of meat and meat products.

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