11th MEMBERS' MEETING (*Part 1*)

Bologna (Italy), November 19 – 20, 2000

Conclusions and Recommendations
Conclusioni e Raccomandazioni

Session

New technologies and methods for the evaluation of the quality of perishable agricultural products for the fresh market

Leading person: ***Luigi Bodria, Italy***

CONCLUSIONS
AND RECOMMENDATIONS

34 experts from **20 Countries** took part in the 11th Club of Bologna Meeting - Part 1, held at the E.I.M.A. show under the aegis of **CIGR** and with the support of UNACOMA, to examine and discuss the following topic:

New technologies for evaluating the quality of agricultural perishables products intended for the fresh market.

Introductory talks on this topic were given by: **J. De Baerdemaeker** (*Belgium),* covering the basic aspects; **J. Zaske** (*Germany*), concerning the properties of plants and the methods for their evaluation; **M. Ruiz Altisent** (*Spain*), on the applicable measurement technologies and instruments.

J. De Baerdemaeker began by noting that consumers are becoming ever more exacting with regard to the quality of food products, and that this entrains considerable changes in the activities of producers and distributors. In fact, they are called upon to meet quality standards that are bound to increase over time, to meet the growing expectations of consumers. Hence the need to propose innovative and non-destructive measurement methods, although their results are - at present - still often difficult to interpret. It is therefore necessary, in the near future, to define precise international regulations, together with the corresponding measurement technologies associated with each method. Another increasingly important problem concerns the need to document each phase of the entire supply chain, from producer to consumer, so that consumers can be informed of the methods used and assured of their conformity to international standards. In the case in point, compliance with standards such as ISO 9000 and HACCP make it possible to guarantee the quality of the productions as a fundamental attribute of perishables intended for the fresh produce market.

J. Zaske provided a comprehensive analysis of the topic, noting the physiological alterations of the various products (amount of water in the product and its freshness; respiration; photosynthesis activity; ripeness and hardness; aroma and flavour) that are correlated with quality. For each parameter, he indicated the possible evaluation methods, discussing their validity, correspondence, limits of applicability, and hence the existing difficulties in obtaining a precise measurement. This with regard to the non destructive methods, which are in large part very recent and appear to be of greatest interest for the future. He also confirmed that an objective quality evaluation must reconcile the needs of the various actors in the entire production chain – from the geneticist to the producer; from the distributor to the consumer – with the specific parameters characterising the physiological qualities of the different crop productions.

M. Ruiz Altisent, referring back to the two preceding papers, pointed out that there is an enormous technology gap, in the fruit and vegetable sector, between the various European harvesting, grading and packaging industries, whose work capacities can vary by a factor of 500. Hence the need to develop instruments and technologies that can improve and harmonize the situation from the quality assurance standpoint, even though the perception and appreciation of these parameters varies considerably from country to country.
Moreover, given the need to unify the technical definitions of quality properties, of the scope and type of each test and the associated measuring instruments, she presented a broad survey of the available instruments for evaluating the mechanical, optical and chemical properties of each product, discussing their advantages and drawbacks. Finally, she called attention to the need for a precise metrological evaluation (sensitivity, specificity, precision, accuracy and reproducibility) of each test, and singled out information systems as a useful tool for testing laboratories, to permit the fast and effective processing of results.

On the basis of the three papers presented, and following an extensive discussion, the

participants unanimously reached the following

Conclusions and Recommendations

- **Underline** the growing importance - in market terms and in view of its globalisation – of the sector under discussion, which only in recent years has been taken into consideration by its primary actors (producers, sellers and purchasers), and by international research centres and laboratories.

- **Recognise** the fundamental importance of defining standards for the instrumental evaluation of the various products, and hence the need to identify specific instruments and technologies appropriate to the various sizes of enterprises involved.

- **Point out** the need for a specific definition of quality parameters and for an evaluation of appropriate instruments and technologies for creating solutions that are effective and transferable to the operational reality.

- **Call** for an adequate commitment to defining reference standards for the quality and reliability of the proposed equipment, with particular reference to those that are most widely used, in order to guarantee conformance to the expectations of consumers.

- **Propose** that the topic should be periodically reviewed by the Members of the Club, in order to evaluate its progress and call upon public authorities, enterprises and consumers to insist on the conformity and compatibility of the results.

- **Invite** the presidency of the Club, therefore, to undertake the promotion of initiatives aimed at answering the above mentioned needs.

CONCLUSIONI
E RACCOMANDAZIONI

34 esperti provenienti da **20 Paesi** hanno partecipato all'11° Meeting – 1ª parte del Club of Bologna, organizzato presso l'E.I.M.A. sotto gli auspici della **CIGR** e col supporto di UNACOMA per esaminare e discutere il seguente argomento:

Nuove tecnologie per la valutazione della qualità dei prodotti agricoli deperibili destinati al mercato del fresco.

Sull'argomento hanno presentato relazioni introduttive: **J. De Baerdemaeker** (*Belgio*), sugli aspetti di base; **J. Zaske** (*Germania*), sulle proprietà delle piante e i loro metodi di valutazione e **M. Ruiz Altisent** (*Spagna*), sugli strumenti e le tecnologie di misura applicabili.

J. De Baerdemaeker ha iniziato ricordando che i consumatori sono sempre più esigenti sulla qualità dei prodotti alimentari il che richiede considerevoli cambiamenti nel comportamento dei produttori e dei distributori. Ad essi, infatti, vengono imposti standard di qualità destinati ad ampliarsi nel tempo sì da incontrare il crescente apprezzamento dei consumatori. Da qui l'esigenza di proporre metodi di misura innovativi di tipo non distruttivo i cui risultati, tuttavia, sono, al momento, spesso causa di difficoltà di interpretazione. Occorre, pertanto, definire precise normative internazionali - con le relative tecnologie di misurazione proprie di ciascun metodo – per il prossimo futuro. Altro problema di crescente importanza riguarda l'esigenza di considerare l'intera catena dalla produzione al consumo con relativa e progressiva registrazione di quanto avvenuto, sì da informare i consumatori sui metodi adottati e sul loro rispetto degli standard internazionali. Il rispetto di norme, come la ISO 9000 e l'HACCP, consente, in merito, di garantire la qualità delle produzioni come attributo fondamentale del prodotto destinato al mercato del fresco.

J. Zaske ha sviluppato una completa analisi della tematica evidenziando le modificazioni fisiologiche dei vari prodotti (stato dell'acqua nel prodotto e sua freschezza; respirazione; attività fotosintetica; maturità e durezza; profumo e sapore) correlate alle produzioni di qualità. Per ciascun parametro ha indicato metodi di valutazione, discutendone la validità, la rispondenza e i limiti di applicabilità e, quindi, le difficoltà attuali di esatta misurazione. Ciò con riguardo ai metodi non distruttivi – in gran parte nuovissimi - che appaiono quelli di maggiore interesse per il futuro. Analogamente, ha confermato che un'obiettiva valutazione della qualità deve combinare le esigenze dei vari attori dell'intera catena di produzione – dal genetista, al produttore; dal distributore, al consumatore – con i parametri specifici propri delle qualità fisiologiche delle diverse produzioni vegetali.

M. Ruiz Altisent, richiamandosi alle due relazioni precedenti, ha evidenziato, per la frutta e la verdura, il grosso divario di livello tecnologico esistente fra le diverse industrie europee di raccolta, classificazione e impacchettamento, le cui capacità di lavoro variano, fra l'una e l'altra, di un fattore 500. Da qui l'esigenza di realizzare strumenti e tecnologie atti a migliorare e omogeneizzare la situazione in termini di garanzia di qualità anche se la percezione e l'apprezzamento di tali termini variano grandemente fra i differenti paesi.
Rilevata, inoltre, l'esigenza di unificare il significato tecnico di proprietà della qualità, di ampiezza di ogni prova, di tipologia della stessa e i relativi strumenti di misura, svolge un'ampia analisi delle strumentazioni disponibili per valutare le proprietà meccaniche, ottiche e chimiche di ogni prodotto, discutendone vantaggi e limiti. Infine, richiama l'esigenza di una esatta valutazione metrologica (sensitività, specificità, precisione, accuratezza e riproducibilità) di ogni prova e indica i sistemi informativi come utile strumento di cui dotare i laboratori di prova consentendo la rapida ed efficace elaborazione dei risultati.

Sulla base delle tre relazioni svolte e dopo approfondita discussione, i partecipanti unanimi pervengono alle seguenti

Conclusioni e Raccomandazioni

- **Sottolineano** la crescente importanza - in termini di mercato e in vista della sua globalizzazione - del settore in discussione che solo da pochi anni è oggetto di considerazione da parte sia degli attori primi (produttori, venditori ed acquirenti), sia di laboratori e centri di ricerca di livello internazionale.

- **Riconoscono** di fondamentale importanza la definizione degli standard di valutazione strumentale dei vari prodotti cui consegue l'esigenza di identificazione di precise strumentazioni e tecnologie appropriate alle varie dimensioni delle imprese coinvolte.

- **Rilevano** l'esigenza di una specifica definizione dei parametri qualitativi e di una valutazione delle strumentazioni e tecnologie appropriate alla creazione di soluzioni efficaci e trasferibili al mondo operativo.

- **Auspicano** un adeguato impegno alla definizione di standard di riferimento della qualità e dell'affidabilità delle attrezzature proposte, con particolare riguardo a quelle di più diffusa utilizzazione, al fine di garantire la rispondenza alle aspettative del consumatore.

- **Propongono** che l'argomento venga periodicamente portato all'analisi dei Membri del Club sì da poterne valutare i progressi e da richiamare gli organismi pubblici, le imprese e i consumatori ad esigere la rispondenza e la compatibilità dei risultati.

- **Invitano**, pertanto, la presidenza del Club a farsi promotrice di iniziative mirate a soddisfare le suddette esigenze.

OPENING SESSION

WELCOME ADDRESSES

Aproniano TASSINARI
President of UNACOMA - ITALY

Good morning Ladies and Gentlemen, I am happy to extend the most cordial welcome to the President Giuseppe Pellizzi and to the entire participants to this 11th Club of Bologna Meeting and to express my gratitude for the work done. The forum of experts was founded in 1989 with the purpose to study and define strategies for the development of agricultural mechanisation in the various countries, considering the technical, economic and social developments in agriculture at word level. The Club has grown in importance and authority over the years; it has developed such fundamental issues as those of sustainable agriculture, new criteria for machinery design, the role of electronics and methods for identifying optimum criteria for mechanisation and the transfer of technology to developing countries. Finally, it has been able to transfer the results of its work in the directions of strategy and policy. The work of this forum looms in importance because of its cultural substance and it is characterised at least by two factors: a global vision of mechanisation, open to all problems and, in touch with various geographic and economic situations, a great prospective for the future open to views for identifying the trends that agriculture and agricultural mechanisation will reach in the coming years. The Club brings together academic figures, researchers, manufacturers and representatives from institutions in 47 countries as well as from such international organizations as FAO, UNIDO, the Asian Development Bank, CIGR; the Club's international character is especially evident by the fact that the work sessions of this year have been, or will be, held in three different countries. The first session was dedicated to prospect the mechanisation for the Latin American countries and was held in July in Fortaleza, Brazil. It coincided with the annual conference of the Brazilian Society of Agricultural Engineers; the second is the present and it is focused on new technologies and methods for certify the quality of perishable agricultural products for the fresh food market. The third one will consider the ethical side of the agricultural machinery manufacturing and will be held at the end of this month in Tsukuba, Japan on the occasion of the 14th CIGR World Congress. Among these issues chosen for these three sessions the first is of special political and economic interest, because it analyses the mechanisation needs and the precise development models for a given area, as the second too. The third involves to create norms for the enterprise in the light of the economic and markets globalisation. Also evident is how much work remains for extending the various components of the technical sector to meet expectations of social stability, environmental responsibility and quality of life in the advanced countries as well as in the developing nations. At the same time this view towards the future qualifies the Club as one of the liveliest institutions working in the technical and scientific field. Full of ideas it has in fact demonstrated that it is possible to control economic development and guide technical and business chooses with a long-term view. In this light the Club of Bologna is also a value point of reference for everyone working in the sector of agricultural mechanisation and agriculture; it is a group capable of looking at with intuitions, analytic spirit and a sense of responsibility. Thank you.

Luigi BODRIA
Leading person - ITALY

I must thank you, Mr. Tassinari, for your statement, as well as the President Pellizzi and the whole Management Committee for the great honour they give me, being here as chairman of this interesting session on new technologies and methods for the evaluation of the quality of perishable agricultural products for the fresh market. This subject has an increasing importance in the evolution of the agricultural market, where the competition among the different countries is becoming harder year-by-year. The quality of products may be a very important key factor for the success of a production. We have the example of Italy, which was in the past the strongest producer of vegetables and fruits, while nowadays we see in our market products from foreign countries, because sometime our production has had a quality level not enough high to compete on the market. From the other side we have to consider the evolution of information technology that allows the increasing of quality controls opening a great number of new technologies that may be able in reducing costs and improving the quality. We have here three speakers who will try to describe the general situation, and I am pleased to give them the floor to start our session.

SESSION

New technologies and methods for the evaluation of the quality of perishable agricultural products for the fresh market

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QUALITY CONSIDERATIONS FOR THE FRESH PRODUCE MARKET

by ***Josse De Baerdemaeker***
Belgium

1. Introduction: The European market for fruit and vegetables

The European Community is considered by all producers worldwide as a very large market and penetrating that market could be very rewarding. The size of that market for fruits and vegetables is given in **Table 1** [1]. The data shown are for fresh and processedproducts.

There is self-sufficiency for vegetables. Tomatoes are more than one third of the imports of fresh vegetables, followed by cucumbers with only 10% of the share. The imports of fresh fruit have risen by 30% in the last five years. One third of this import are apples. At the same time apple plantations in Europe have expanded considerably and approximately 20% of the harvest had to be destroyed in 1992. The imports in citrus are mainly juices. Over the years one sees increases in exports as well as in imports for all fresh produce. There has also been an increasing diversification of the products.

The intra-EU trade shows product flows that are much larger than those at the EU borders do. It has increased by about 10% for fresh fruit and vegetables and stayed nearly constant for citrus. These figures are only averages and larger changes occurred for some products

Another characteristic of the European market is the regional differences in consumer's preferences for products. This is so for vegetables and even more so for fruit. Also, total vegetable consumption (including potatoes) varies between countries, from an impressive 261 kg/year in Greece to only 116 in Germany [2]. Catering to these non-uniform consumer preferences in the single market is a challenge

The international trade negotiations and the necessary changes in the common agricultural policy of the EU (or CAP) has forced or convinced a number of farmers to shift their production from crops with market regulations such as wheat or sugar beet to free trade crops such as potatoes, fruit and vegetables. The per capita consumption of fruit and vegetables has only increased by 1% over the last five years. That for citrus has increased by 8% but appears to level off. The new and old producers as well as importers are competing for the same stomach and apparently only substitution is taking place.

The above data indicate that quality claims are becoming more and more important to maintain or increase a market share. The other problem is that with so many new entrants in the market a good system of quality standards and checks must be maintained to keep the confidence of consumers.

2. Product Quality: from producer to consumer

The term quality seems to be very frequently used when talking about the market in Europe for fruit and vegetables. Produce quality is a claim and a demand that one finds in the local stores, in the supermarkets and in the co-operatives and distributors offices. The call for improving and maintaining product quality, to strengthen the competitiveness of the growers is equally found in government programs, both national and pan-European. The difficulty then is that Product Quality can have many definitions depending on which position in the chain from primary production up to the consumer. The following are some considerations of fresh produce quality. They are adapted from [3].

2.1. The definition of product quality

The understanding of the term Product Quality has been subject of a large number of studies. Juran (3) has included the consumer in his concept of product quality and prevention instead of control of quality. His definition is "Quality is fitness for use". With

respect to the situation for food products a better wording would be "Quality is to meet the expectations of the consumer". Two important aspects should be underlined here. The first one is that the consumer is the starting point of thinking about quality and the second is that the consumer does not work with accurate specifications. The consumer doesn't exist. There is no average consumer. There is a specific consumer who, in a specific situation and at a certain moment, has a specific need to which the producer can respond. A food product as such has no quality, it has intrinsic and extrinsic properties which are transformed into quality attributes by the perception of the consumer

The consumer buys and consumes a product for a number of reasons. Partly these reasons refer to product properties for another part these refer to the production system. proposes The use of the terms intrinsic and extrinsic factors is proposed by [3]. Intrinsic factors refer to physical product properties such as flavour, texture, appearance, keepability and nutritional value. Properties that are direct and/or indirect measurable and that can be objectively determined. An example of this is the texture of an apple. From a physico-chemical point of view the texture of a product can be described in terms of cell wall composition and structure. The overall elastic and rupture properties of the product can be measured. The consumer perceives this during consumption and describes his experience in terms of crispiness or mealiness and toughness The total of quality attributes (intrinsic factors) determines the quality of a given product. Extrinsic factors refer to the production system and include factors such as the amount of pesticides used during growing, the type of packaging material used, a specific processing technology or the use of biotechnology to modify product properties. They do not necessarily have a direct influence on physical product properties but influence the acceptance of the product for consumers. The total of intrinsic and extrinsic factors determines the intention to purchase.

The consumer is the driving force for product innovation and the consumer generally views quality from the product-based perspective as has been described above. Indeed products should meet consumer needs and it is the task of the marketing to identify the needs specified for the type of products that can be produced. A product that meets consumers' expectations can rightly be described as having good "quality" and therefore marketing people work with a user-based definition of quality.

The next step is to translate consumers' expectations into product characteristics and process specifications. Making this translation is the role of R&D, product design and engineering people. Product specifications address such things as size, appearance, taste, safety, keepability, and nutritional value. Process specifications include the harvesting methods, the packaging, sorting and storage and transportation conditions required. A primarily concern is the variation in product quality that can occur as a consequence of e.g. seasonal variations and cultivar differences. Nevertheless the producer must adhere to the design specifications. The production-distribution cycle is completed when the product has been moved via wholesale and retail outlets to the consumer. Distribution does not end the relationship between the consumer and the producer so service-oriented concepts of quality cannot be ignored by the producer.

2.2. Production system characteristics

Product innovation in the fresh produce industry has to deal with a number of characteristics, which make it complicated to achieve quality control throughout the chain.

1. Food products are perishable and depending on the conditions, product properties can change very fast and result in spoilage. This means strict quality demands for production, storage and passage time throughout the production chain.
2. Production and harvest of plant foods is seasonal whereas consumers ask for constant availability. So there is a requirement for adequate storage and/or transport methods and facilities.

3. There is a clear awareness amongst consumers about the relationship between diet and health. This includes both the absence of unwanted components such as pathogens and toxicants, either naturally present or added, as well as assuring the levels of components that are wanted such as vitamins and minerals. Adequate risk prevention requires systematic quality control.
4. Small-scale production is an obvious characteristic of plant foods and a complicating factor in assuring homogeneous product. It requires specialised organisational structures. Co-operatives like the auction markets can play an important role here.
5. The number of retail outlets is very large which complicates an adequate control of distribution quality (service oriented). The retail outlets also have to deal with a large number of wholesalers. This makes it virtually impossible to define accurate specifications with respect to quality demands for a given product.
6. Fresh food products are perishable and have only a very limited shelf-life. It makes it too expensive for retailers to maintain large amounts of produce in store. This has resulted in systems with very high frequencies of delivery.

2.3. Product quality in the production chain

Different concepts of product quality are used by the various actors in a specific production chain. The following example of the large number of quality criteria is given by [2] a plant food product has to meet and how these differ from the breeder to the consumer.

- Breeder: Vitality Seeds, Yield;
- Grower: Productivity, Uniformity, Disease resistance;
- Auction: Uniformity, Reliable Supply, Constant Quality;
- Distribution: Keepability, Availability, Damage Sensitivity;
- Retailer: Good Shelf-life, Diversity, Appearance, Low waste;
- Consumer: Tasty, Healthy, Sustainable, Convenience, Constant Quality.

It may become obvious that no single product can meet all the requirements indicated and that there is a clear need for one integrated concept of product quality throughout any specific supply chain.

Another characteristic that holds has to do with the notion that for plant products during growth product quality is built up whereas storage and handling are primarily concerned with prevention of quality loss. This means that differing concepts have to be applied.

During growth knowledge about the relationships between agronomical conditions, cultivar properties and harvest moment is of great importance for a good shelf-life during storage and handling for fresh products and for adequate processing conditions for fabricated foods. Quality loss is inevitable because harvesting is in fact a situation of imposed stress and the post-harvest conditions are vital for maintenance of good end-product quality. We are actually talking about living organisms that respire and are metabolically active. The composition and structure of the raw material and the associated processing properties are strongly dependent upon these processes. For a chain oriented system of quality control we need to have methods that can measure external and internal quality and predict keepability.

3. Current quality control practices

3.1. The international and European standards for fruit and vegetable quality

The COMMISSION REGULATION (EU) No 2200/96 of 28 October 1996 is currently the most general regulation that organizes the common European market system for fruits and vegetables. The creation of a single European market for fruits and vegetables was only possible because at the same time agreement was reached on common provisions for standards for products marketed within the EU, imported from or

exported to third countries. For the implementation of the market organization, the Commission also sets trade standards for fresh fruits and vegetables **(Table 2)** that are being offered to the consumers. These standards define the product and have provisions concerning quality, sizing, tolerances, presentation and packaging, and marking. The standards aim at keeping low quality products from reaching the market, at enabling fair competition in the trade and encouraging a fruit and vegetable production that satisfies consumers expectations. The standards apply to all stages in the production and distribution chain, but it is recognized along the chain quality deterioration can occur as a result of biological processes. A continuously updated list of products is given that fall under the market regulation and for which standards are available. EU regulations also lay down the methods of inspection and procedures for conformity checks of fruit and vegetables produced in the Community or for importation into the Community. Member states. It designates the competent agencies for conformity checking. A competent agency may delegate to private agencies to carry out the checks. It may also exempt traders from inspection of goods at the time of consignment. This is only possible provided that the traders in question can guarantee uniform quality of the produce they are marketing and have trained inspection staff and suitable equipment for preparing, packing and pre-cooling the produce. For imports from third countries, a correlation table can be established between the quality classes provided for in the standards applied in the countries in question and those provided for in the common quality standards. Note that additional phyto-sanitary regulations are expected in the near future.

The standards are agreed on in the "Management Committee on Fruits and Vegetables", composed of official representatives of the member states. These committee members consult experts and concerned producers and traders in their respective countries before making decisions on quality standards. The common quality standards of the EU are found as numbered directives in the form of a collection of loose leaflets per product. Where applicable the EU takes into account the international standards agreed on by the OECD (Organization for economic cooperation and development) and/or the Economic Commission for Europe of the United Nations Organization. It is impossible to give details or even summarize these standards here, but from reading through them some generally applied principles can be found that are of interest in the development of automated quality inspection.

The quality standards relate to external properties of the products such as shape, size, appearance, and product presentation. Internal or intrinsic quality parameters (such as taste or sugar content) are in general not specified, although for some products specific regulations or interpretations of the norms may exist. Furthermore, it is required that the product condition and the package can guarantee that the product quality is maintained up to the destination point. The minimal requirements for all quality grades are in general: entire product without damage, free of spoilage symptoms, no parasites, free of foreign material, healthy, no strange smell or taste, no excessive moisture on the outside. The classification is usually done in three or four categories: extra, class I, class II and sometimes class III. These class distinctions relate to admissible defects, degree of coloration, shape irregularities and also to the size variation within a package. Apples or pears in class extra have an allowed size variation of 5 mm; for citrus this is 10% of a minimum size; for tomatoes this variation is specified in mm but depends on the size; for asparagus the admissible diameter variation is 8 mm for a minimum diameter of 16 mm. For lettuce, garlic and kiwis the size classes are expressed by weight. For citrus there are requirements of minimum juice content of the fruit, based on manual pressing, as well as on the maximum of 20% of green color.

Some of the quality requirements are not just external parameters but involve also internal parameters, defects or breakdowns. These are more difficult for interpretation. For example,

the standards for apples and pears specify that these products should be sufficiently ripened in order that they can continue the maturation process and reach a ripeness stage that is characteristic for the variety. These requirements are important for signaling the start of a new season, and each year the Management Committee must translate this into a minimum fruit size combined with an earliest picking or marketing date. Here the starch content can be a guideline for deciding on the maturity stage and this has lead to the development of semi-automatic systems for quantifying the starch content based on image analysis of a cut fruit treated with iodine. It is expected that the test will be used by growers as well as by inspectors.

Similar "fuzzy" requirements can be found for many products. This has led to a large activity for working groups dealing with guidelines for uniform interpretation of the European standards. These working groups are sometimes active within the Economic Commission for Europe, a division of the Organization for Economic Cooperation and Development (OECD) of the United Nations. It is obvious that these interpretations are a very sensitive matter and that some groups of producers may want to influence them in order to gain a commercial advantage or not to loose out if they would not be able to produce or prepare products according to the most stringent interpretations. The discussions between growers from the different European countries, between the inspection agencies and within the working group are usually very long. Within the framework of the activities of the OECD on International standards for fruits and vegetables explanatory brochures with standards, comments and illustrations are published for around 20 products. One of the latest brochures is on carrots. It contains numerous pictures as well as comments related to quality characteristics mentioned in the standards. These brochures facilitate the common interpretation of standards by inspection agencies and professional or commercial organizations that are involved in the international trade in these products. However, it is still not easy to convert these standards and related comments into objectively measurable properties such that automated sensing and decision-making techniques can be implemented for grading and sorting.

3.2. Private conventions for quality

It is clear that the consensus on European standards is related to minimal requirements for the different classes that must be met for obtaining permission to market produce in Europe. A detailed observation of these classes reveals that each can be composed of different grades that satisfy the class standards. Traders and distributors have insufficient information if only the class is mentioned in the marketing. This has lead to the development of private quality grades or private quality requirements. Some examples will be given here.

There has been a rapid expansion of the market in Europe for bi-coloured apples such as Cox, Jonagold and Elstar. The percentage of red color and the green-yellow background color are used for setting up the different grades under classes extra and I. In class extra a 60% red color is required and three grades are made based on the light to dark green background (grades E, E+, E++). In class I the different grades are based on 50, 35, 20% red and each in turn with a light to dark green background. Add to this the size classes that vary by 5 mm and one can see the large number of possible grades. Fortunately not all-possible combinations occur simultaneously during grading one particular lot of fruit. The co-operative auction markets have introduced these grades. At this moment some suitable color sorting lines have been introduced, but for a number of instances or defects sorting is still done mainly by human judgement. Similarly inspectors are employed for the conformity checks to see if the observed grade corresponds with the one indicated by the grower.

The need for a detailed classification arises from the "simultaneous remote auctioning" system that has been build separately in Belgium and in the Netherlands. These are electronic networks connecting all the fruit and vegetable auctions in each country, and slowly both systems are being interconnected.

The remote auctioning implies that buyers may never see the product and they must rely on the established grades that minimize differences in opinion and disputes. This quality classification system may also contribute to the emergence and growth of an e-commerce system for fresh produce

Grading for size and shape has been around for many years. For a while size grading was replaced by grading by weight and the use of a size-weight calibration to satisfy the official standards. Work has been done to use image processing for size grading. In the literature much research in that area can be found. Commercial introduction of equipment using image based grading for size and shape of apples, bell peppers and other products is starting. It should be noted that currently skin defects or bruises still seem to need manual corrections of the sorting result. These surface defects, due to roughness, bruising or cuts during harvest, spoilage and insects are commercially very unprofitable.

Quality attributes other than appearance are getting more and more attention. Firmness is such an attribute for tomatoes, kiwi, apples and pears. Some supermarkets advertise that they sell apples with a firmness or penetrometer value of, for example, at least 6 kg/cm². Tomatoes should have a Zwick reading of at least 43. This Zwick test is applied to samples and is a quasi-static non-destructive hardness measurement using a small spherical indenter. Similar requirements exist for peaches and nectarines.

The main difficulty for automated grading and sorting on the basis of firmness is that horticulturists and traders rely on the destructive tests since they seem to imitate the chewing actions in the mouth. However, such test devices are not easily standardized and the repeatability of such tests cannot be shown. Non-destructive tests can be made such that they measure generally accepted engineering properties, even when different methods for measurement are used. The repeatability and accuracy of these methods can be tested.

The sugar content of melons is a quality parameter that in some markets is measured by taking small cores from the flesh for refractometric analysis. The small holes are filled with wax. This can be considered as a quasi-non-destructive check. Near-infra-red (NIR) sensing technology is under development and close to the market for sugar content measurements in melons, apples and other fruit. Supermarkets are also using acceptance tests that include instrumental measurements for firmness, sugar content or chemical residues.

3.3. Quality management in the production chain

Codes or guidelines for good agricultural practices are becoming very popular for enhancing the consumer confidence in the quality of the product as well as in the quality of the production method.

Grower's organizations like cooperatives have taken the approach of incorporating the production methods as part of a quality assurance scheme towards supermarkets, buyers and consumers. In most cases the products are sold as a brand under a quality label. One example in Belgium is the label "FLANDRIA" which stands for integrated cultivation, extra quality and from family business. Producers realized that health and environment are becoming more and more important for consumers when purchasing food products. A balanced package integrates biological cultivation methods with ecological awareness in crop protection. In addition the producers must register their cultivation practices and they regularly inspected during cultivation and delivery to make sure that they comply with the extremely strict conditions. Exclusion from the use of the quality label implies severe financial penalties.

Shelf-life expectancy is becoming more and more important in the European market. One can consider that the above mentioned firmness requirements are an extra indication that the produce will have an acceptable shelf life as well as satisfy the consumers. Co-operatives are also subjecting fruit or vegetable samples to accelerated shelf-life tests. The product is already sold by the time the results become available, but the information is used for future transactions

with produce from a given grower or for advising growers that some varieties are unacceptable.

An information and product flow diagram for products under such a quality label is given in **Figure 1.** It illustrates that in this concept quality is not just the actual state of the product but also the production method itself plays an important role. In this way the producers and cooperatives have established their procedures and proper standards that are more rigorous and more elaborate than the EU standards. The small, but growing supply of products from biological farming relies on similar guidelines to reinforce the image of healthy quality. In the future also the social conditions at the production or shipping companies may become part of such a quality scheme.

The further implementation of such quality control schemes and the use of information technology will assure that the product can be traced almost completely through the production and distribution chain. A consumer can then at the point of purchase obtain the information on production and distribution methods. Of course, one should make clear to the consumer that he also has a responsibility to assure that quality and safety of the product are maintained from the point of purchase up to the consumption.

Some supermarkets have also taken initiatives to respond to the to the quality consciousness of consumers. They have developed strict guidelines on cultural practices that should be followed by their selected growers. These guidelines include soil type, fertilizers, varieties, plant protection practices, harvest dates and grading requirements. The growers or suppliers are being rewarded for helping the supermarket to maintain its quality image. One such initiative is EUREP, in which supermarkets from a number of European countries discuss the GAP (good agricultural practices) guidelines for growers. The growers can also be cooperatives and in this respect the initiatives of growers and supermarkets appear to converge.

3.4. Hygiene codes, HACCP and ISO 9000

Growers pay a lot of attention to their cultural practices and to grading and sorting produce according to the standards laid out either by Governments or by their clients. In recent years more and more attention is also being paid to the food safety aspects of fresh produce. It has always been assumed that fresh produce is the best there is and that no food safety risks are present. This was perhaps true when the market chain was still relatively short. Nowadays this chain is a little longer because of the cold storage, the packaging and repackaging of the product into smaller units, the longer transportation distances etc. Each additional manipulation involves people and may pose treats to contaminate the product either with foreign material or with micro-organisms.

It is then important that for all the steps involved in bringing the produce to the consumers measures are taken to reduce the health risk by contamination or otherwise to a minimum. One approach is the hygiene code, another more elaborate one is the HACCP. HACCP stands for Hazard Analysis Critical Control Point. It originated from the US space program where it was imperative to supply the astronauts with food that had the least possible health risk caused by manufacturing or handling methods. HACCP is now being widely introduced in food processing plants. Application of HACCP has recently also started in the fresh produce chain.

HACCP is a system for achieving proactive food safety to insure that food is safe before distribution. It requires a systematic application of tested technologies, which if applied correctly will control food hazards. It starts with an analysis of the food handling or production flows. The potential hazards and how they can enter in the material flow are then identified. Places in the system are then identified where a proper action or operation will reduce or eliminate the hazards. These are the control points. The system is analyzed to ensure that all recognized hazards are controlled such that the resulting food products are safe. To implement it in the handling systems a structured, well-defined,

set of activities for each control point are devised to insure that the control methods and technologies are applied correctly. Proper instructions for people at the critical control points, monitoring procedures and appropriate record keeping are part of the implementation.

The ISO 9000 series is a set of five individual, but related, international standards on quality management and quality assurance developed to help companies effectively document the quality system elements to be implemented to maintain an efficient quality system. They are generic, not specific to any particular products. Manufacturing and service industries can use them alike. The ISO 9000 Series standards do not themselves specify the technology to be used for implementing quality system elements. The standards were developed by the International Organization for Standardization (ISO), a specialized international agency for standardization composed of the national standards bodies of 91 countries.

ISO 9000 provides the user with guidelines for selection and use of ISO 9001, 9002, 9003 and 9004. ISO 9001, 9002, and 9003 are quality system models for external quality assurance. These three models are actually successive subsets of each other. ISO 9001 is the most comprehensive - covering design, manufacturing, installation, and servicing systems. ISO 9002 covers production and installation, and ISO 9003 covers only final product inspection and test. These three models were developed for use in contractual situations such as those between a customer and a supplier. ISO 9004 provides guidelines for internal use by a producer developing its own quality system to meet business needs and take advantage of opportunities.

ISO 9000 guides a company to build quality into the product or service and avoid costly after-the-fact inspections, warranty costs, and rework. In addition, it may also be able to reduce the number of audits customers perform on an operation. For this, the ISO 9000 series provides the company with a quality system that:

- standardizes, organizes and controls operations;
- provides for consistent dissemination of information;
- improves various aspects of the business based use of statistical data and analysis;
- acceptance of the system as a standard for ensuring quality in a global market;
- enhances customer responsiveness to products and service;
- encourages improvement.

Increasingly, customers are accepting supplier quality system registration from an accredited third-party assessment based on these standards. Having a quality system registered to ISO 9001, 9002, or 9003 generally involves having an accredited independent third party conduct an on-site audit of a company's operations against the requirements of the appropriate standard. Upon successful completion of this audit, the company will receive a registration certificate that identifies its quality system as being in compliance with ISO 9001, 9002, or 9003. The company will also be listed in a register maintained by the accredited third-party registration organization. The company may publicize its registration and use the third-party registrar's certification mark and the accreditation body's mark on its advertising, letterheads, and other publicity materials (but not on its products).

One could argue that HACCP could be a part of an ISO 9000 registered quality system, specifically focussed on food safety aspects of an operation.

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Figure 1 – Flow Diagram Flandria

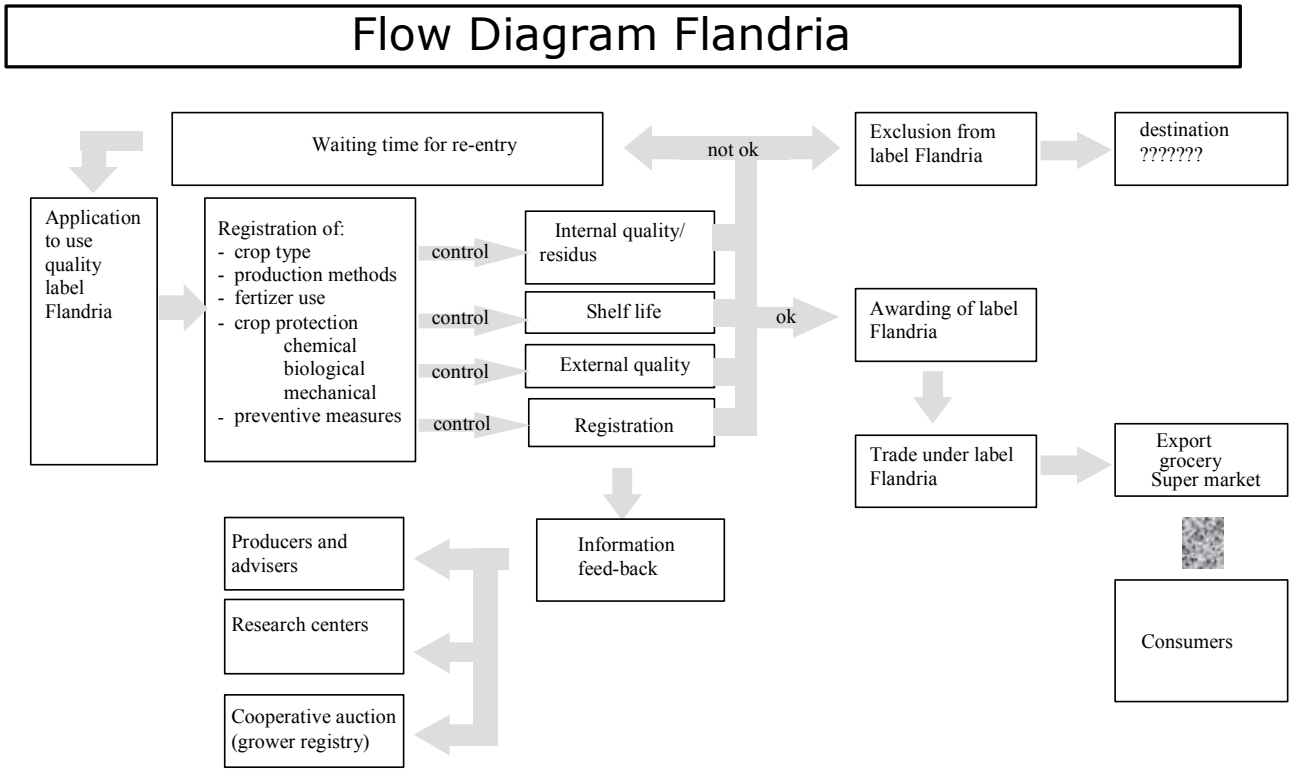

Table 1 - Market data for fruit and vegetables in Europe for 1991 (in 1000 ton). Data include fresh and processed products and juices; data in parenthesis are for fresh products only [1]

	VEGETABLES	FRUIT	CITRUS
Production	47101	21201	9222
Import	2802 (940)	5833 (2237)	4626 (1636)
Export	4663 (672)	1416 (654)	907 (864)
Intra-EC trade	8331 (5135)	5247 (4284)	3434 (2511)
Human consumption (kg/head)	119	64	35
Self-sufficiency (%)	104	83	71

Table 2 - Fresh products covered by EU quality standards

Strawberries	*Fragaria L.*	Bell peppers	*Capsicum annuum L.*
Apricots	*Prunus armeniaca L.*	Pears	*Pyrus L.*
Endives	*Chicorium endiva L.*	Peaches	*Prunes Persia L.*
Apples	*Mauls L.*	Leeks	*Gallium proem L.*
Artichokes	*Cygnet scolymus L.*	Plums	*Prunus L.*
Asparagus	*Asparagus officinalis L.*	Oranges	*Citrus sinensis L.*
Aubergines	*Solanum melongena L.*	Lettuce	*Lactuca sativa L.*
White celery	*Apium graveolens L.*	White cabbage	*Brassica oleracea L.*
Cauliflowers	*Brassica oleracea L.*	Beans	*Phaseolus vulgaris*
Lemons	*Citrus limon L.*	Spinach	*Spinacea oleracea L.*
Courgettes	*Cucurbita L.*	Brussels sprouts	*Brassica oleracea L.*
Peas	*Pisum sativum L.*	Table grapes	*Vitis vinifera L.*
Cherry	*Prunus L.*	Tomatoes	*Solanum lycopersicum L.*
Kiwi	*Actinidiae*	Onions	*Allium cepa L.*
Garlic	*Allium sativum L.*	Brussels chicon	*Chicorum intybus L.*
Cucumber	*Cucumis sativum L.*	Carrots	*Daucus carota L.*
Mandarines, Clementines	*Citrus reticulata L.*		

EVALUATION OF THE QUALITY OF PERISHABLE AGRICULTURAL PRODUCTS FOR THE FRESH MARKET. PLANT PROPERTIES AND PLANT PARAMETERS

by ***Jürgen Zaske, Martin Geyer, Bernd Herold*** *and* ***Werner B. Herppich***
Germany

1. Introduction

According to [1] the term quality implies the degree of excellence of a product or its suitability for a particular use. Quality is a human construct comprising many properties or characteristics. Quality of produce encompasses sensory properties (appearance, texture, juiciness, taste and aroma), nutritive values, chemical constituents, mechanical properties, functional properties and defects.
The definition of quality for perishables is complex. People use all of their senses to evaluate quality: sight, smell, taste, touch, and even hearing. The consumer integrates all of these sensory inputs – appearance, aroma, flavour, hand-feel, mouth-feel and chewing sounds – into the final judgement of the acceptability of that fruit or vegetable. Instrumental measurements are preferred over sensory evaluations for many research and commercial applications, because instruments reduce variations among individuals, are more precise and can provide a common language among researchers, industry and consumers [1]. The relationship of the instrumental measurement to sensory attributes to consumer acceptability must be considered [2].

2. Fruit and vegetable quality

In the previous contribution [3] enumerated six items which make a standardised determination of ripeness of fruit and vegetables so difficult.

A further obstacle to standardised quality determination is the vast amount of fruit and vegetable species. The single species belong to various plant families. From a morphological point of view, the produce to be analysed consists of leaves (lettuce, spinach), roots (carrots), flowers (broccoli, cauliflower) or fruit (tomatoes, beans, apples, strawberries **Table 1**. Being part of such a large spectrum, they distinguish themselves in their physiological behaviour during postharvest, each requiring different climate conditions during storage.

For the purpose of quality determination, each variety must be assessed according to its own, specific criteria. For green vegetables, which wilt easily due to their large surface, freshness is important. Therefore, especially the parameters connected to water status are decisive. With fruit vegetables the interior parameters which make up taste, such as sugar and acid content and their proportion, are important in addition to water status.
As far as fruit are concerned, an additional problem posed by the specific ripening behaviour of each fruit species must be dealt with. So-called climacteric fruit such as apples and pears go through different stages of ripeness characterised by the formation and transformation of quality-relevant substances. This development also takes place during storage, as long as the fruit have not been harvested too early. The producers' goal must be to time harvest and storage in such a way, that the fruit reach their optimum degree of ripeness only when they get to the consumer. If the fruit are harvested too early, they are insufficiently ripe, remain sour and have a bland taste or are subject to other physiological damage. If the fruit is harvested too late, the fruit get to the point of sale when they are overripe, their resistance to mechanical stress declines, which causes greater losses. Non-climacteric fruit do not ripen during storage. An unripe orange or plum, for example, does not become sweet, but their substance content remains constant. These substances are merely degraded until the fruit rots.
The aim and the challenge is the development and application of non-destructive methods and processes, which can either measure quality parameters (colour, form) directly or

can deduce these parameters, e.g. by measuring firmness. Another important requirement here is the capability to make predictions about quality changes under defined storage conditions, in order to make reliable statements about the shelf life of a product.
Below, we demonstrate by means of different examples how one can deduce the quality and the degree of ripenes of perishables through the recording of specific physiological parameters of the plant.

3. Physiological changes related to produce quality

3.1. Product water status and freshness

Freshness denotes an important aspect of produce quality, although it is not very well defined in a scientific sense. On the other hand, well known from many commercial spots, freshness is of outstanding importance to consumers in this context. Seemingly it enables them to sense produce quality, at least partially, with their eyes, noses or hands. From its appearance combined with their own, very subjective experiences and expectations, consumers believe - or at least hope - to be able to assess the potential taste and the nutritional value of the produce. However, freshness is a complex, multivariate issue. Therefore, the question arises whether freshness of perishables can be defined or measured in an objective scientific manner.

In leafy greens, for example, transpirational water loss may rapidly result in visible wilting, largely reducing the market value of the product. Thus, tissue water status is an important determinant of freshness for many vegetables and fruits [4].

Water status as well as its variations can be described in terms of absolute or relative water content (or water deficit) and as water potential **Figure 1**. Ideally, at harvest a produce will have a high water status which means that its water content should be close to its maximum. Water potential, a measure of the “potential” capacity for water uptake should be almost zero because its components, the osmotic potential and the pressure potential are at nearly the same level under these conditions.

If water loss cannot be prevented which is very often the situation in postharvest, both water potential and pressure potential decline with increasing tissue water deficits. As indicated by the definition of the volumetric modulus of elasticity, pressure potential - or turgor - largely determines tissue elasticity. It must be mentioned that, on the other hand, the capability of the pressure potential to change with water volume is determined by the cell wall and the overall tissue elastic properties. Because the variation of the osmotic potential with water content is low, water potential and pressure potential are highly and positively correlated with physical tissue properties like fracture toughness and tissue elasticity. For these reasons, these parameters are related to crispness.

From this, it can be deduced that freshness is characterized by a water potential ranging between zero and the wilting point where freshness certainly ends. This also means that water potential provides a kind of absolute measure, while the determination of water content or water loss does not necessarily fulfill this requirement.

Comprehensive knowledge about water relations may be important to meet the demand for an objective determination of product quality as well as its changes during postharvest. In addition, it may help to improve methods and machines for mechanization and automatization in the entire postharvest handling process [4].

There are several established methods available to measure water potential as well as its components at different organization levels of a product, i.e. for the whole organ, at tissue or at cellular level [5]. Most of them are, however, more or less destructive and may not allow for a large sample size to be measured. The pressure chamber, on the other hand, has been successfully used to non-destructively investigate the influence of postharvest handling on water potential of storage tubers such as carrots or radish. In-situ dew point hygrometer may continuously follow the variations in leaf water potential in

several vegetables. The pressure-volume-analysis technique has been used to translate water potential into its components and to model their variation with changes in water content; a result of it has been shown in **Figure 1**.

Unfortunately, there is no truly non-invasive, rapid method available to remotely measure water potential or water content. Magnetic resonance imaging seemed to a great potential in this respect. However, this technology is very expensive and difficult to operate and may therefore not be useful in routine control of produce quality [1].

As mentioned above, in harvested products the short-term variation of the water status is due to transpirational water loss. Measuring transpiration rates may provide additional insight into aspects of quality and quality preservation. However, transpiration is influenced by both environmental conditions (humidity and speed of the surrounding air) and product properties (size, shape, surface, temperature, etc.). Therefore, the determination of an average tissue resistance or conductance (i.e. the inverse resistance) to water loss (often less exactly termed transpiration coefficient) largely eliminates the environmental effects (**Fig. 2**). In addition, it has been shown that the rate of water transfer out of the tissue declines as its water potential and water content decrease. The determination of the tissue resistance may, therefore, provide a different method to estimate produce water status.

Under conditions of free convection it is possible to determine the average product tissue resistance from concomitant measurements of mass changes (i.e. by weighing), produce and air temperature, and air humidity, after assessing the boundary layer resistance (which depends on the form and size of the produce). The fruit or vegetable could be obtained from any point of the postharvest handling chain. Nevertheless, it is essential to re-hydrate it to near water saturation, to assure comparability. From the data obtained it is possible to calculate an external water status, which is totally independent of environmental conditions [6].

Several investigations showed that the produce tissue resistance may vary with the age at harvest. It is also affected by preharvest methods (irrigation, nutrition, average climatic conditions etc.) as well as postharvest handling conditions (mechanical and climatic stress etc.).

From the given examples it is evident that transpiration is a very important parameter for the evaluation of produce quality and the quality changes during postharvest handling. Transpiration is classically determined with different types of porometers or, as described before, simply by repeated weighing. Although these techniques are non-destructive, they do not provide the capability of remote sensing. This however is an essential prerequisite of continuous quality control during pre- and postharvest.

In this context improved thermographic image analysis is a promising tool that has already been used successfully in crop science. Because rates of transpiration and hence evaporation are directly related to the rates of heat consumption from the evaporating surface, it is possible to calculate water the loss from the temperature depression of the product. Thermography can therefore be used to investigate the consequences of climatical stress or mechanical impacts on product quality, as shown in **Figure 3**. With this method it is also possible to elegantly detect local damage of the produce both mechanical or by infection [7].

3.2. Respiration

It should be kept in mind that fresh products are not dead; they are still living and metabolically active plants or plants organs. Several physiological parameters indicate the activity of highly regulated biochemical and biophysical processes. Postharvest handling may influence several of these processes one of which is respiration. Vice versa measurements of respirational activity can help to indicate the effects of different processes that may influence the quality. For an example, mechanical impacts during washing, sorting and packing of carrots may seriously stress the produce without inducing visible external damage [8]. However, these

stresses increase respiration rates relative to carefully hand-harvested controls, although to a very different degree, as indicated in **Figure 4**. This, in turn, reduces the content of value adding substances such as free sugars and several organic acids. Thus, respiration measurement may help to improve single processing steps by indicating their stress potential and estimate relative contribution on the overall quality decline.

In steady-state systems respiration rates are established with high-resolution infrared gas analysers (IRGA) measuring the CO_2 evolution. Determination of the O_2 consumption is more complicated because normal atmosphere provides a much higher O_2 background. Newly developed O_2 analysers with a resolution of up to 1 ppm now allow investigation in parallel to CO_2 in open systems. This may give valuable indications of the respired substances thus allowing more detailed interpretation of the respective mechanisms involved.

3.3. Photosynthetic activity

As discussed before, a high internal quality of a produce may imply a high activity of certain metabolic mechanisms. In green, chlorophyll-containing tissues photosynthesis is a physiological pathway of outstanding importance. As photosynthesis is a very complex, highly regulated process, the determination of the photosynthetic activity of a produce may provide a means of – at least partially - quantifying its quality. Such investigations are normally done by measuring either the rates of CO_2 uptake or the O_2 production. During recent years a somewhat more elegant method has become available, the so-called chlorophyll fluorescence analysis [5].

Chlorophyll molecules are incorporated in very specialized protein complexes located in the chloroplastic membranes of photosynthesizing cells. Chlorophylls are the major light harvesting pigments providing the photochemical energy that is converted into metabolically usable biochemical energy in the overall process of photosynthesis. These molecules may also nearly instantaneous emit some of the absorbed energy as light of somewhat lower energy. Under normal conditions this fluorescence is of minor importance, representing 2 to 3% of the total absorbed energy. Most of this energy is orderly converted into biochemical energy or is safely dissipated as heat when the energy supply exceeds its demand (**Fig. 5**). However, when biochemistry is restricted in certain stress situations, energy flow is directed into both heat and fluorescence.

Based on energy flow models, the analysis of chlorophyll fluorescence kinetics measurements allows the separation of both overall photochemical and heat dissipation processes. With modern pulse-modulated fluorometers several important fluorescence parameters can be determined within one single procedure. Without going too deep into detail, using these parameters it is possible to quantify the overall photochemical efficiency of the produce, as well as the relative contribution of processes, i.e. heat production, to the dissipation of the absorbed radiational energy.

Measured in a defined light, temperature and humidity regime, the maximum photochemical efficiency or the respective fluorescence coefficients of photochemical and non-photochemical processes may be used to characterize the overall produce quality. They are also often used to detect the negative effects of unfavourable postharvest handling. Variations in some or all of these fluorescence parameters are for example induced by chilling stress, heat stress, mechanical stress, fungi infection, herbicide stress, etc. or during senescence.

On the other hand, stress responses may also be used to indirectly evaluate internal produce quality. As mentioned before, high quality of a fresh product is linked to high physiological activity. This, in turn, includes the ability to rapidly acclimate or to respond to a certain stress and show a short relaxation period after removal of the stress. Thus, measuring the responses to or the relaxation time after the application a defined stress provides a valuable and fast means to test product quality.

However, standard fluorometers only allow spot measurements. This is in part unfavourable, because photosynthetic stress response may have a high local (**Fig. 6**) as well as time-dependent dynamic over a leaf or a fruit. This effect is difficult to correct for and can induce a high degree of variation. A very promising solution of this problem is chlorophyll fluorescence image analysis. As fluorescence image analysis can be used continuously and remotely, it may be combined e.g. with thermographically investigation of the transpirational water loss. This non-destructive and non-invasive method may yield comprehensive estimates of produce quality.

3.4. Maturity and ripeness

3.4.1. Optical properties

The stage of maturity at harvest of pome fruit is generally recognized as one of the main factors determining the duration of storage life and ex store quality. Different fruit characteristics have been considered as indicators for the optimum harvest date for long-term storage. [9] proposed to include fruit respiration, ethylene development, starch degradation and fruit flesh firmness as important parameters for the estimation of the optimum harvest date (**Fig. 7**). Pome fruit exhibit a typical climacteric behaviour when reaching the maturity stage. The decreasing tendency of the respiration rate comes to an abrupt stop and it increases again. Parallel to this increase, a considerable ethylene development occurs. Besides a distinct starch degradation and a gradual decrease of fruit flesh firmness take place. Starch degradation (especially apples) and firmness (especially pears) have gained wide application but these methods are not sufficient to identify the optimum harvest date in all years. Measurements of apple fruit characteristics in certain intervals some weeks before the estimated harvest date are only reliable for single orchards or specific cultivars [10]; he created a maturity index including 3 parameters: firmness according to the Magness-Taylor test, refraction (% Brix) and starch conversion stage. He found that this index values were specific for each tested cultivar but rather independent from influence of the orchard or the annual climatic conditions. A model for the prediction of the optimum harvest date based on the Streif index. Has been investigated by [11]. However, the high standard deviation indicated that the application of the method to individual orchards is not possible yet.

At present, extensive research takes place on developing additional, fast and non-destructive methods to improve these ripeness models.

During the harvest period, additional fruit parameters undergo distinct changes:

- changes in chlorophyll content of the fruit skin and associated cell tissue which represents the ground colour of the fruit;
- changes in blush colour pigments which develop in dependence on fruit variety, sunshine intensity and diurnal temperature course;
- changes in the specific content of water and of carbohydrates (e.g. sugar) in cell tissue beneath the fruit skin.

The changes of these parameters can be measured quite precisely by using optical spectrometry in the visible and near-infrared wavelength range. Optical properties are correlated with the visual appearance of a fruit or vegetable which is a primary factor in quality judgements of fruit and vegetables. Light reflected from the product carries information used by inspectors and consumers to judge several aspects of quality. However, human vision is limited to a small region of the spectrum. Colorimeters measure light in terms of a tristimulus color space that relates to human vision; they are restricted to the visible light region. The incorporation of fruit colour might further improve the Streif index as proposed by [11]. This reasonable suggestion was not proved, since the former use of L*a*b* - values only insufficiently describes the colour changes during fruit development [12]. Some changes in quality features like the chlorophyll content can only be accurately monitored in a spectra. During fruit development a shift in the balance of

chlorophyll breakdown and synthesis appears. Chlorophyll synthesis is reduced in mature apples, which gradually reduces the chlorophyll content. Thus, this decrease in chlorophyll content may be considered as a sensitive indicator of the stage of fruit development [13]. Some quality features respond to wavelengths in regions outside the visible spectrum. Spectrometers and spectrophotometers measure wavelengths in the UV, visible and NIR spectral regions; instruments are optimised for a particular wavelength range. Thanks to recently developed accurate and inexpensive spectrometer devices, the optical spectrometry has become a very promising technology.

Optical properties are based on reflectance, transmittance, absorbance, or scatter of light by the product. When a fruit or vegetable is exposed to light, about 4% of the incident light is reflected at the outer surface, causing specular reflectance or gloss, and the remaining 96% of incident energy is transmitted through the surface into the cellular structure of the product where it is scattered by the small interfaces within the tissue or absorbed by cellular constituents [14]. The complex physical structure of tissues creates an optically dense product that is difficult to penetrate and alters the pathlength travelled by the light so that the amount of tissue concerned is not known with certainty. Most light energy penetrates only a very short distance and exits near the point of entry; this is the basis for colour. But some of it penetrates deeper (usually a few millimeters, depending on optical density) into the tissues and is altered by differential absorbance of various wavelengths before exiting and therefore contains useful chemometric information. Such light may be called diffuse reflectance, body reflectance, diffuse transmittance, body transmittance, or interactance; these terms are not always clearly distinguished.

Recently, the characteristics of light reflectance and light transmittance have been compared by using a miniaturized spectrometer with glass-fibre bundles and adequate sensor probes for reflectance and transmittance measurements on the apple fruit [15]. The (diffuse) reflectance has been measured by using an integrating sphere. A special sensor probe has been used to acquire the (partial) transmittance. For this reason the ends of an emitting and a receiving fibre bundle have been placed on fruit surface spaced 10 mm apart. When the transmittance was measured, stray light from environment was excluded.

The related light interactance spectra of “Jonagold” apples at two different dates are given in **Figure 8**. The measured wavelength range consists of the visible light (400 to 700 nm) and the sort wave part of near infrared light (700 to 1100 nm). Within the visible wavelength range, the major absorbers are the pigments: chlorophylls, carotenoids, anthocyanins. Both the reflectance and the transmittance spectra exhibit in visible range typical minima at the chlorophyll absorption band near 680 nm. There are clearly different reflectance and transmittance values when comparing the calendar weeks 35 and 44. The spectral curves of calendar week 44 show a steeper slope in the wavelength range below 580 nm which may indicate the increasing light absorbance due to pigments of blush colour on the fruit skin. In the wavelength range above 680 nm, i.e. in near infrared range, only the transmittance spectra show appreciable differences. In the near infrared region, chemical bonds of water, carbohydrates, fats and proteins absorb light energy at specific absorption bands. Some of the major absorption wavelengths for pigments, fats, proteins, carbohydrates and water are listed by [16]. There is a vast amount of literature on optical measurement of pigments and other constituents and on their relationships to maturity and quality. In this range there are absorption bands of water at 980 nm and of carbohydrates at about 900 nm which might become more evident if light penetrates a certain volume of cell tissue.

To quantify the chlorophyll content in plants, a well-known method is the determination of the position of the inflexion point at the long-wave flank of chlorophyll absorption band at 680 nm [17]. In this way, the decrease of chlorophyll content during progressing fruit

maturity can be expressed by the shift of the inflexion point on the wavelength scale. This wavelength shift has been taken from the light transmittance spectrum of `Jonagold´ apples over a period of 13 calendar weeks (**Fig. 9**). The position of the inflexion point is nearly linear correlated with the time ($R^2 \approx 0,68$). These results have been validated by means of reference analysis of chlorophyll content.

Currently, multiwavelength or whole-spectra analytical methods are being developed for the non-destructive determination of soluble solid content (SSC), acids, starches and ripeness. Starch or soluble solids content can be determined in intact fruit (apple, citrus, kiwifruit, mango, melons, onion, peach, potato and tomato) with $R^2 \approx 0,93$ and SEC (standard error of calibration) ≈ 0.5% SSC.

Differences between sound and damaged tissues in visible and NIR diffuse reflectance are useful for detecting bruises, chilling injury, scald, decay lesions and numerous other defects. Bruises on apples and peaches can be detected at specific NIR wavelengths. However, the wavelengths chosen for apples differ between fresh and aged bruises because of drying of the injured tissues.

3.4.2. Mechanical properties

Mechanical properties relate to texture. Mechanical tests of texture include puncture, compression and shear tests, as well as impact, sonic and ultrasonic methods [1]. Under mechanical loading, fruits and vegetables exhibit viscoelastic behaviour. The viscoelastic behaviour has a minimal contribution to perceived texture in most firm fruits and vegetables (e.g. apple or carrot), but is quite significant in soft fruits like tomato or cherry.

Firmness of horticultural products can be measured by compression or puncture with various probes at different force or deformation levels, depending on the purpose of the measurement and how the quality attributes are defined. Horticulturists tend to define firmness as the maximum force attained. The maximum force is defined as firmness in the popular Magness-Taylor penetrometer test and usually also in the Kramer multiblade shear test.

3.4.3. Fruit contact pressure distributions - equipment

For a better understanding of the behaviour of fruits and vegetables during mechanical loading, the contact pressure distribution between fruit and contacting surface should be known. Recently, a tactile sensing system has been developed. This sensor consists of a thin flexible plastic film containing a grid of sensitive material which responds according to the pressure at each of the points on the mesh. This tactile sensor, originally developed to help dentists determine how well a patient´s teeth were contacting, allows the pressure distribution between contacting surfaces to be determined in real-time [18].
The general pressure pattern for apples pressed against a flat steel plate is shown in **Figure 10**. The pressure was greatest in the centre of the contact area, diminishing towards the edge in a roughly parabolic shape as predicted by elastic contact theories. However, when the load in the center exceeded the sustainable maximum, there was a sudden drop in pressure at the centre, corresponding to the bio-yield point. This was accompanied by an increase in the contact area. After this break-down the pressure distribution changed so that the greatest pressure was at the edge of the contact circle. The average central pressure fell to about half the level just prior to failure, while the pressure at the edges was typically as high as twice as much as the average central pressure. Subsequently, as the load continued to increase, there were further increases in the contact area.

The sensor helps to understand the physical properties of fruit and vegetables at different development stages for mechanical loading. It can also be used to measure the pressure distribution between fruit and other curved surfaces, including fruit to fruit contact, or for the assessment of cushioning materials used in packaging [19].

3.5. Flavour and taste

An important quality criterion of fruits is their taste. With increasing ripeness, flavour and

taste increase until senescence is reached (**Fig. 11**). A relatively new approach is the measurement of these volatiles with "electronic noses". The concentration of volatiles within a fruit or vegetable increases as it ripens and their release to the surrounding atmosphere is responsible for the products' pleasing aroma. In the same way off-flavours are developed, for example when damaged fruit are moulding. Aromatic and non-aromatic volatiles are released to the surrounding atmosphere. For this, different measuring principles are available.

The sensors are not specific for particular volatiles, each type is generally sensitive to a particular class of compounds. A battery of several detectors can produce a "fingerprint" that may indicate maturity or presence of some disorders. Different factors which should be optimised to get reliable results with these specific gas sensor – arrays, are mentioned [21]:

- headspace-temperature;
- headspace-humidity;
- headspace-volume;
- headspace-pressure;
- sensor-temperature;
- purity of the carrier gasses;
- mass flow of the carrier gasss;
- probe volume and surface;
- headspace-desorption time;
- injection time;
- kind of sensor;
- sensor signal preparation and statistical methods.

Further research is needed to explore the selection of detectors and to relate the fingerprints to quality categories.

4. Conclusion

It is very complex to objectively measure and to define the quality of fruit and vegetables. Depending on the wide range of different products and their specific physiological development in postharvest, product specific evaluation criteria have to be selected. An objective quality evaluation has to combine the needs and requirements of the various actors in the production chain – breeder, grower, auction, distribution, retailer, consumer – with the specific physiological quality-relevant plant parameters.

The most interesting quality measuring methods in the future will be non-destructive which can be detected on-line during processing. For example, some optical systems are already used in practice, other systems like the electronic noses or non-destructive water state measurements are in the development stage.

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Figure 1 - Relationship between water potential, osmotic potential, pressure potential and relative water deficit, as established from pressure-volume–analyses with fresh carrots. The derivation of the volumetric modulus of elasticity from changes in pressure potential and water volume is indicated

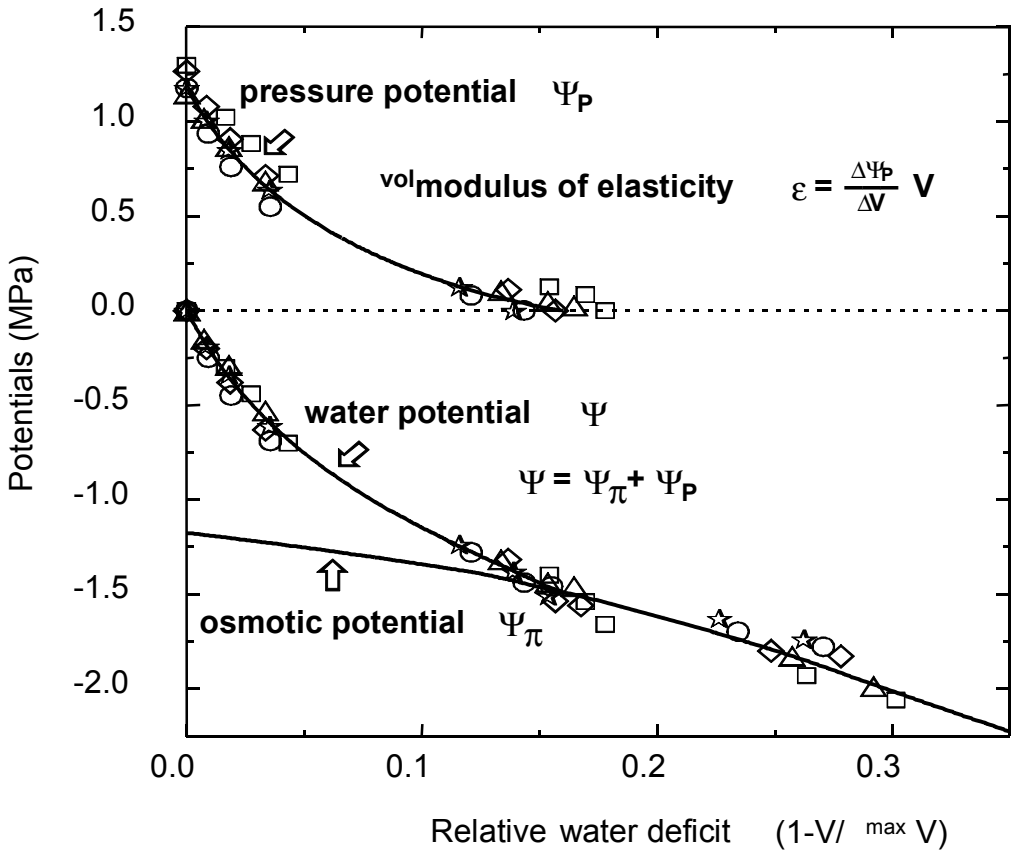


Figure 2 - Simplified model of the determination of the average tissue resistance to water loss of radish tubers

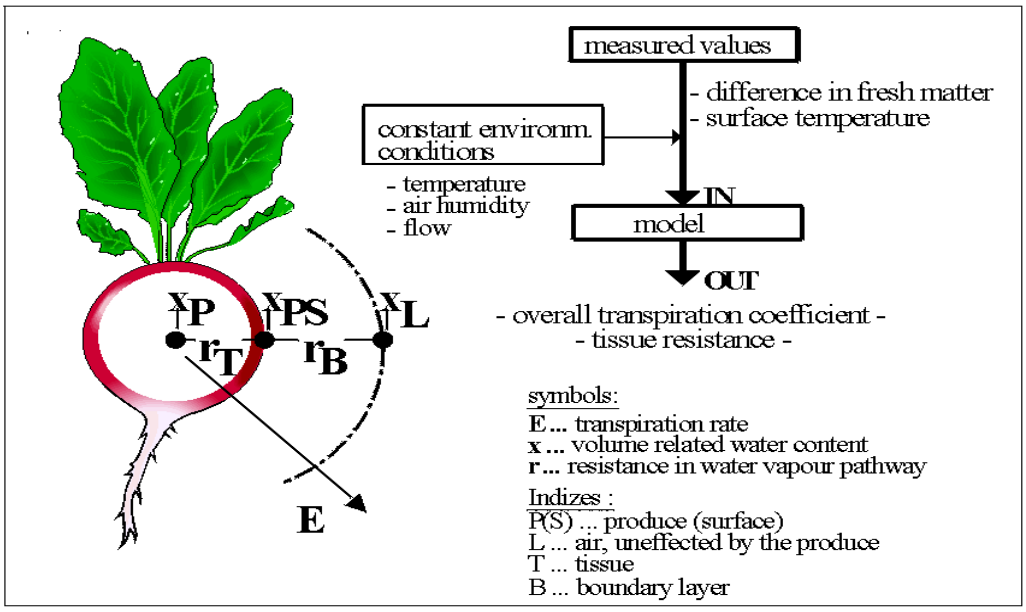


Figure 3 - Thermo image of carrots before and after washing (left ... level 2 - high intensity; middle ... level 1- lower intensity; right ... two unwashed references)

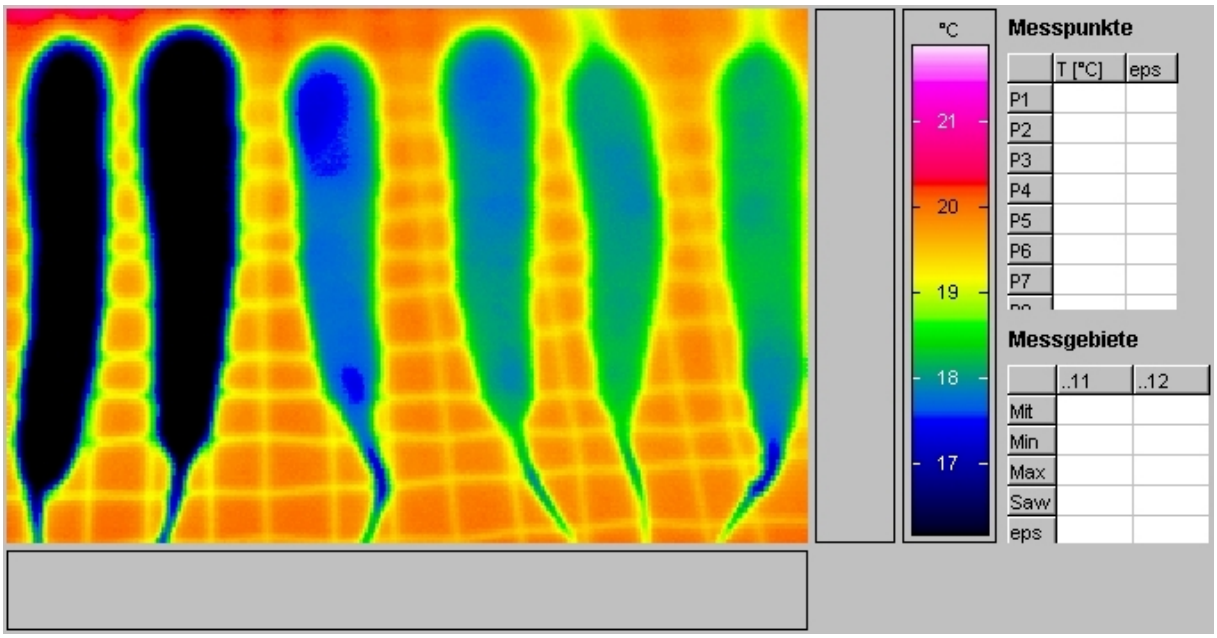


Figure 4 - Influence of mechanical impacts during different step of a packinghouse line on the quality of carrots

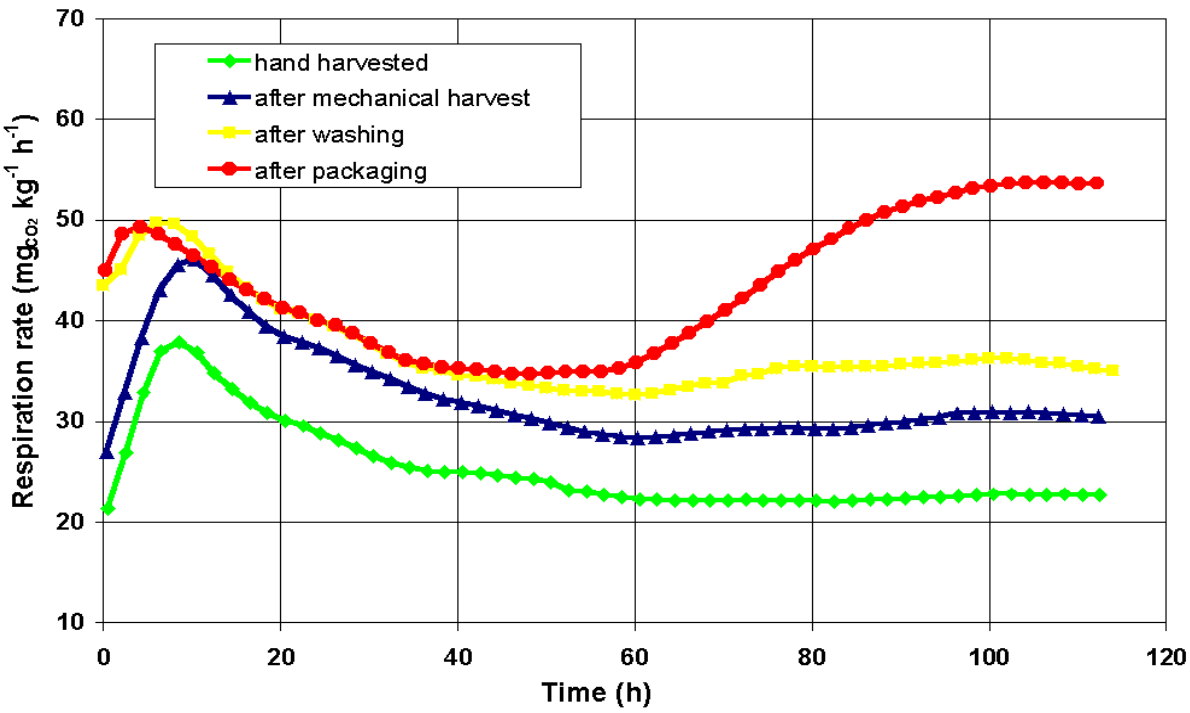


Figure 5 - Model of the relative photosynthetic energy flow in unstressed and stressed plants

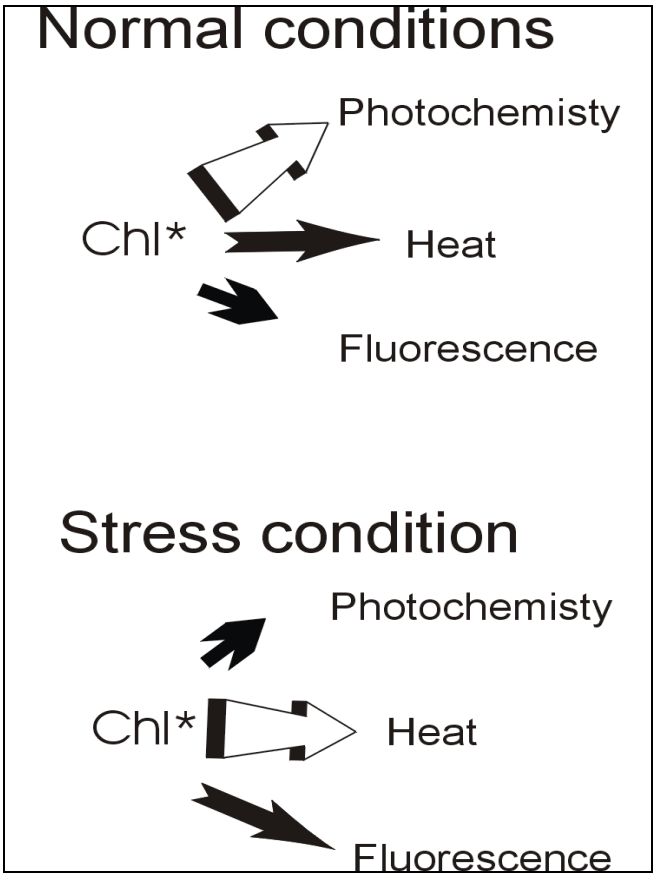


Figure 6 - Variation of the maximum photochemical efficiency (F_v/F_m), and the coefficients of photochemical
A and non photochemical (heat) processes over a large leaf

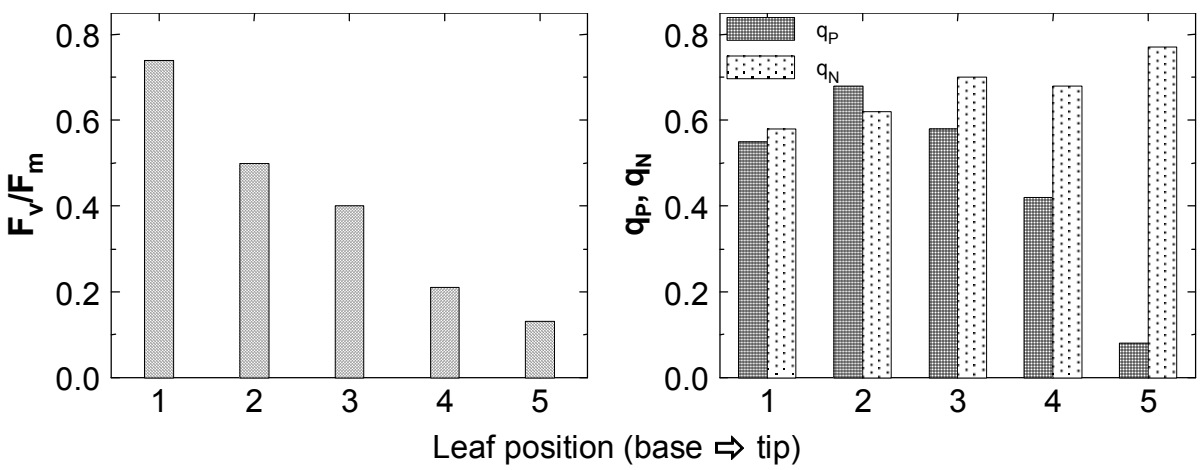


Figure 7 - Physiological development and optimum harvest date of climacteric fruit for long-term storage

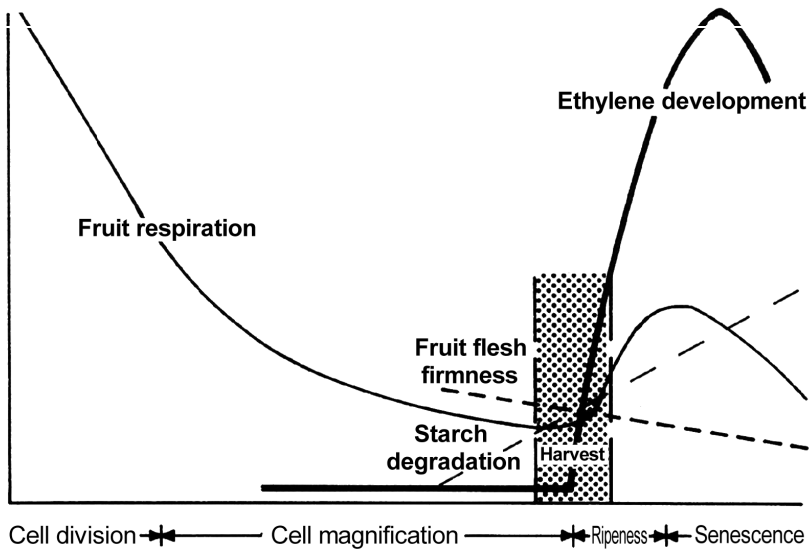


Figure 8 - Spectral light reflectance and transmittance of "Jonagold" apples at different development stages

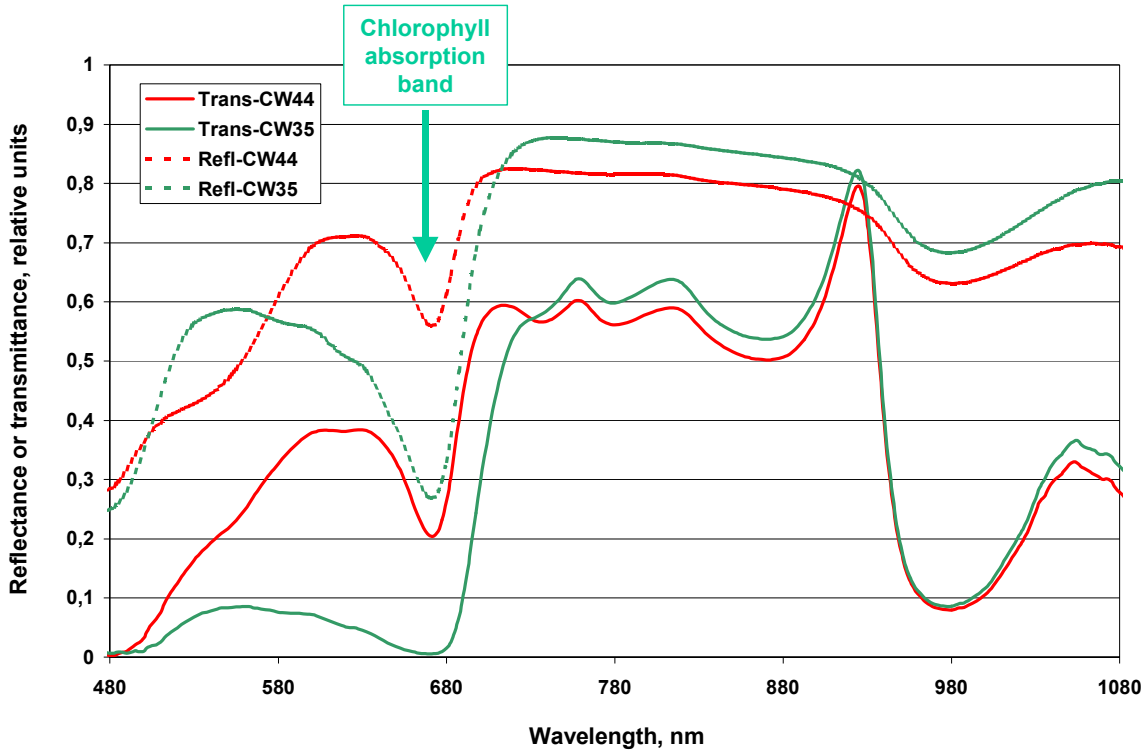
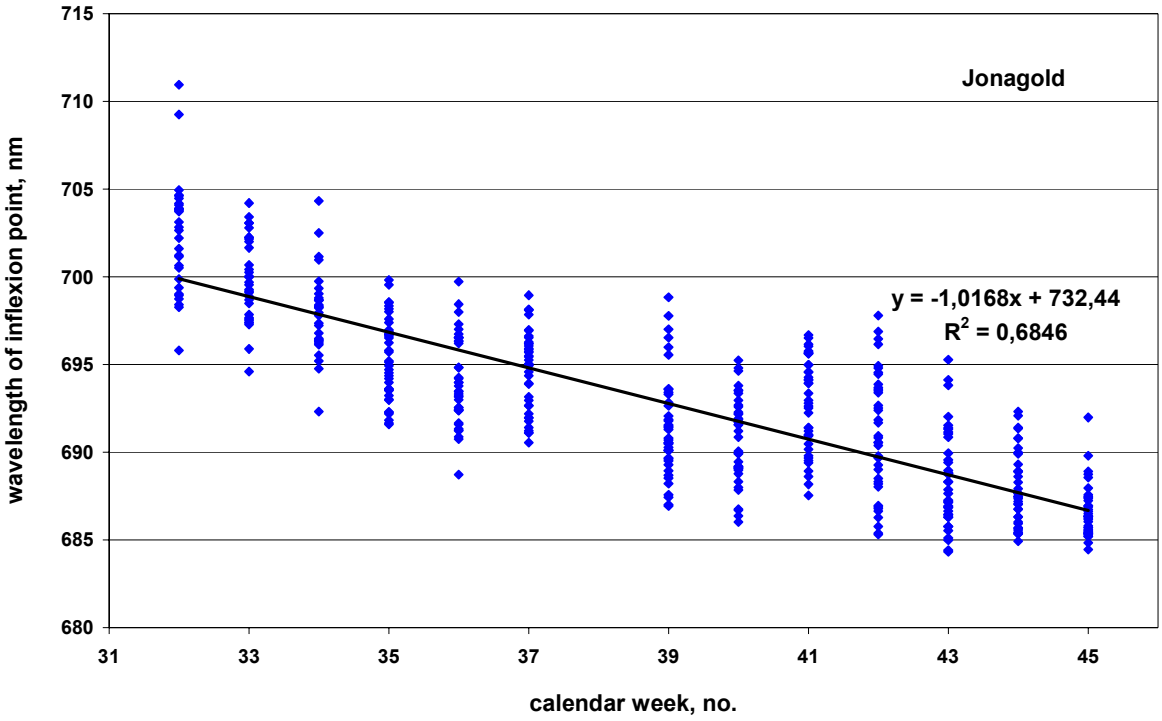


Figure 9 - Wavelength shift of inflexion point in slope of the long-wave flank of chlorophyll absorption band in "Jonagold" apples during the period from August to November



QUALITY IN FRUITS AND VEGETABLES: FROM SENSORY PERCEPTION TO INSTRUMENTAL MEASUREMENT

by ***Margarita Ruiz-Altisent, Pilar Barreiro***

Spain

1. Quality standards and consumer valuation

At least three different concepts are encountered when referring to "quality" of a food product: a) the relative to the qualified origin and/or procedures of field production; b) the one referring to quality systems used in production and (mainly) in processing, according to the ISO 9000 and further standards, which are discussed in other parts of these presentations.

The third, and what I am referring in my contribution, can be defined as the accordance between consumer's expectation and its satisfaction when eating (in general, consuming) the product. The properties that confer this satisfaction to the product have been called "intrinsic" properties. In the market, valuable "quality" standards have been developed, defined for every single product, which have greatly enhanced the globalization of the market of fresh products. The quality properties that are standardised in the regulatory body are those that every product in the market has to be comply with.

The properties which may be standardised have to be such that, either there exist some magnitudes to be measured, like: size, shape, presence and size of external damages, or else they are not included in the standards. Some properties may be (and are) included, based on subjective evaluation (colour, and its distribution, typical varietal features, occurrence of off-shapes). It is obvious that regulations can not include properties which can not be measured with defined protocols. It is well known that all this has drawn the market to a point where many fruits and vegetables do not satisfy the consumer: in many cases beautiful fruit (for example peaches, or pears) are completely inedible; others are tasteless (as mealy apples).

One example is the practice of "degreening" of oranges. The present standards establish minimum colour for the mandarines; at the beginning of the season, colour of these fruits is still mostly green; so, there exists the technique of degreening, which consists of a treatment in a closed chamber where ethylene is applied at specific temperatures and times. The peel develops a beautiful orange colour, apt for the market, but the sugars in the inside flesh are non-existent. Growers and distributors are now concerned on developing: for one hand, the relevant instrinsic properties that the consumer will accept: sugar and acid contents, aromas (juice content is already established as a more or less standard measurement) also Vitamins; the magnitudes which characterise these properties: ºBrix, total acid content, in ml/kg; or pH; content, in mg/kg of ascorbic acid or carotene; and third: establish the instruments and protocols to carry on the measurements at the production site, and possibly at the auctions. This involves sampling strategies, equipment selection and installation, data acquisition and management systems, decision aids, all of them needing a feasible and cheap solution.

2. Economic potential of quality in the sub-sector

A continuous trend of increase in the market quantity and value of fresh produce is observed, being the most important basis their image of healthiness and their relationship with "greenness". In fact, in the last years, breeding of new varieties is looking for taste, aromas, and also vitamins and other pigments content, to comply with this recognition. These issues are more specifically discussed by Prof. De Baerdemaeker in his presentation.

The data on vegetable and fruit production and its economical value have been presented by the first author in this meeting. Let me

make some estimation of the relevance of the *equipment* that is used to handle, classify and pack the European fruit and vegetable production. Using detailed data from the two largest federations of Cooperatives (in Spain) and from some large companies, between 8,000 and 12,000 packing plants (i.e. full-equipped handling lines) are in operation today in the EC. The range of sizes is huge (between 2,000 and 1 million tons per year per plant), and so is also the technological level of those plants and equipment. We may appreciate the large possibilities for equipment manufacturers to develop instrumentation and improving implements in this sub-sector.

All actors in the production-distribution chain are potential users of instruments and equipment for measuring fruit and vegetable quality properties. The pressure now exerted by those potential users is giving impulse to technological development, with the aim to solve the frequent problems arising in the negotiations between those actors. Also some agro-insurance agents and technology transfer institutions are potential users of this equipment.

What these users ask for may be summarised in: objectivity, sensibility, precision, reproducibility, portability, fast and easy operation, possibly non-destructiveness, accessible reference materials; extension of use and low cost. The priority given to these requirements depends on the different applications: Control laboratories need a lower portability, whereas a higher robustness; "fast" operation may be a priority for manual operation (laboratories at line): on line, automatic applications demand a high-speed 10 fruits per second operation. Finally, low cost is also relative: It may be established in 400 Euro for the growers and 4000 Euro for on-site laboratories; (up to 40,000 Euro for research laboratories) [1] per instrument unit.

3. Human perception of quality

On the European, and on the global market of our times, one very much discussed question, which is sometimes used to point out the impossibility of meeting the consumers expectations, is that the consumers of different areas (markets, states) have different appreciation of fruit and vegetable quality. This, for one hand, is not completely true, as we will analyse in an example on quality of apples. On the other hand, if there is such different groups of consumers, the market should be able to inform them properly and reliably on the (intrinsic) properties of each product on the shelf, so that they can make their choice and be satisfied.

Recently, in the scope of a European joint R&D project dealing with apple quality, one of the Institutions made a very detailed study on consumers (apple) preferences from different nationalities: UK, Danish, Flemish, French, Spanish and Belgian [2]. On a first sensory panel test, 41 attributes were assessed, as for example: hardness, crispness, juiciness, watery, green sweet, floral, bitter, etc: these are named "descriptors" by the sensorial experts. Then, a repertory grid with 125 consumers was carried out with three different apple varieties in every country. The terms were translated into the different languages, after previous consumer studies. The conclusion of this study was that:

- the overall perception of the descriptors for the quality of apples is similar, what suggests "a cross-cultural consensus with respect to consumer perception" (of mealiness in apples), and hence of these selected sensory attributes, in this well known fruit (**Fig. 1**);
- on the other hand, it was shown that, being this specific "intrinsic" property ("mealiness") similarly perceived, different consumers might have different appreciation of it: most of them do not like it, some of them did.

This is good news, as there appears the possibility of developing instrumentation (as was in fact done for mealiness) to measure the properties, whose results can be used to define more precisely any fresh product for the choice of the consumer.

4. Properties, magnitudes, tests and scales

On the previous basis, the market begins to accept that the features which the consumer relates to its perception of quality when eating fresh products are indeed "quality (intrinsic) properties" of the product itself. This opens the possibility for analysing these properties and advancing to its instrumentation.

In the aim to develop instruments and systems for measuring fruit quality, we can distinguish four different concepts:

- first a "property", or quality property: it is rather an idea, well known by most consumers and experts, which lacks a precise physical meaning (for example: firmness or consistency);
- second a "magnitude", which is the value of a parameter with a defined physical significance and units (for example: puncture force (N) or force/deformation (N/mm); modulus of elasticity (N/m^2);
- third, we need the definition of a "test" and an instrument with a testing protocole: (for example: probe rupture by compression or by extension; Magness-Taylor or Effegi penetrometer; non-destructive impact or sonic response meter);
- fourth, we need the definition of a "scale": the distance between consecutive divisions. Scales may be linear or non-linear; non-linear scales are usually the ones which relate best to sensorial perceptions.

To be able to quantify a property it is necessary to use some magnitudes which are closely related. Being this relationship not evident in many cases, a *sensory panel* is needed at the first stage (as described earlier in the case of mealiness). In other cases, a clear or common-sense relationship exists between a property and a magnitude (firmness measured by resistance to penetration, N/m^2). There is the need for the development of new instruments to measure properties which already have an instrumental reference: this is why new techniques are searched, searching for an advantage: instruments that are faster, non-destructive, more portable, more reliable, more precise and accurate, etc.

5. Instrumentation for the assessment of quality properties

The process of "instrumentation" used for the development of instruments is a complex action that involves all phases included in **Figure 2**: from the description of the property, selection of the magnitude and the appropriate test, experiments for calibration, scaling, construction of the prototype, field validation, definition of reference values, up to the marketing phase.

Table 1 shows a summary of different (intrinsic) qualitative properties of fruits and vegetables as they are generally accepted today, and associated in each case magnitudes and instruments currently in use for their measurement. They may be considered in a stage of "generalised use" and therefore as "de facto" standards. Weight and size instruments are not included, as they are much more widely used and well known.

5.1.Mechanical properties and instruments

There exist a very wide selection of instruments to measure *firmness*. The penetrometer (Magness-Taylor) is the oldest and most accepted. This test has never been studied with metrology protocols, as no reference exists for it. It has many problems of reproducibility, and of the range of validity. The rest of firmness-measuring instruments are considered non-destructive. We have: acoustic resonance (AIR.KU Leuven), impactometry (LPF-UPM) and Durofel (Copa-Technology). Each of them yield different magnitudes, which are badly correlated to destructive penetrometer values, as they measure rather deformability, more closely related to hand-hardness sensory appreciation. Destructive penetrometry resembles more to "biting" firmness; the correlation improves when using penetrometer force/deformation ratio rather than force.

Turgidity is directly related to water status, being turgor or pressure potential (Pa, as

explained in Dr. Zaske's contribution) the magnitude used for its measurement. The complexity of this magnitude needs specialised laboratories. In the case of pome fruits, though, we have shown [3] that deformation at puncture with a 0.5 mm-diameter rod is very indicative of the turgor stage of the (external tissue of the) fruit, being "freshness" but also susceptibility to bruising well correlated to this property of the fruits.

New technologies are being searched for firmness measurement of produce. The main objective being its non-destructiveness, assessment of the whole fruit-body, and adaptability to on-line instrumentation. *Magnetic Resonance*, using surface measurement rather than 3-D imaging is a possibility [4].

Scattering properties of any material, and therefore of a tissue, are related to structure: number, size, shape, cell-wall and disposition of cells influence light scattering. A new technique called *TDRS* [5] is being tested with some success, and a prototype is already in validation process. It uses VIS and NIR laser wavelengths applied through a single optical fibre, and detection is accomplished by photon-counting equipment. Estimation models were established for firmness in kiwis, peaches, apples, and other fruits based on absorbance and scattering values of three to seven wavelengths.

Conventional NIR light beams have been already tested with similar results. NIR light is absorbed by some constituents in some wavelengths, so that the selection of the optimal areas to measure scattering is crucial. Very recently, microwaves are being studied with similar objective.

Juiciness, described as the amount of juice that is easily liberated on biting the fruit, is not necessarily related to total water content. It is mostly related with the way the tissue breaks at biting. So, mealy texture is "dry" because the cells do not break, but rather separate [6]; turgid and densely packed cells break and release the juice [7], as happens in the so-called "crisp" textures. The instrument called Chylofel consists in the introduction of a probe of fixed volume (2 cm^3) and recovery of the released juice. With a calculated density of the juice of 1 g/cm^3, the percentage of juice in it can be determined. This test, lacking a correct metrological evaluation as no reference materials exist for it, is not very precise, and can only be used as fruit sample average, and not to obtain individual fruit data; an advantage is the technique for extracting the juice sample, that is very reliable.

5.2. Optical properties and instruments: Colour and vision systems

The existing equipment to objectively evaluate colour is carried out with *colorimeters* and spectrometers in the visible (VIS) range. Both instruments give co-ordinates XYZ, Lab and L*a*b*. The first (XYZ) were defined in the 1930s by the CIE: Commission International de l'Éclairage, and they reproduce the human vision for a normalised viewer. Human visual perception is much sharper in the greens than in the reds, and so do the XYZ co-ordinates. The colour spaces Lab and L*a*b* give a more objective representation of colour differences between the products (something very important in post-harvest ripening!). L*a*b* are a small modification of the Lab established by CIE in 1974 to improve the uniformity of distribution for the different cromatic surfaces.

Spectrophotometers are able to register point reflectance values for (very) small areas of the spectrum (between 5 and 20 nanometers wide windows) and therefore can evaluate specific pigments, as chlorophyll [8]. Variations in this and in other pigments are better correlated to, for example, post-harvest ripening processes.

Colour may also be measured by image: colour or grey distribution maps or images. This is the system nowadays used in commercial on-line equipment. When using image, the added possibility is to determine colour distribution. The combination of image and spectroscopy, which produces spectral imaging, is the great development in fruit classification equipment [9] For example, bruises can be much better "seen" by a camera when using spectral images at specified wavelengths than when using complete light. Moreover, these spectral

images can be combined together to better enhance specific surface damages.

Artificial *vision* is widely used today in on-line equipment for sizing. Usually, a combination of a UV, VIS and a NIR (or black and white) CCD cameras are installed on every fruit line, with which size and shape is determined for grading fruit according to standards, and colour and colour average or distribution, according to market requirements (**Fig. 3**). The present need imposed by the manufacturers of an output of 6-10 fruits per second seems quite incompatible with the precision in size grading (1-2 mm in diameter in oranges) imposed by standards.

5.3. Chemical properties and instruments: Taste and aroma

These are the "intrinsic" properties the consumer expects to find in a fresh, high-quality fruit or vegetable. And these are probably the most difficult (or time-consuming) to measure at present. We count with two instrumental methods: First, soluble solids, SS, (more or less closely related to "sweetness", depending on the fruit considered) are measured by refractometry. *Refractometers* are very common in most laboratories, they count with reference standards and are very precise and reliable in themselves. A disadvantage is that they are little specific, as soluble solids, and moreover, ºBrix, are not always referring to the same chemical composition. Refractometry is destructive, as they need a few drops of juice on the instrument. This also happens with acids determination, as the acidity measurement also needs some juice to be titrated in a solution; (more-or less) automatic *titrators* help in the assessment of high numbers of samples in the laboratory. The uncertainty of these procedures lies in the recovery of the juice, which may introduce much variability in the results. The content of sugars and acids both add to the taste of a fruit or vegetable. We have to bear in mind that both are "dissolved" in the sap; if no sap is released, no taste can be sensed: textural characteristics are closely correlated with chemical flavouring factors, as has been well demonstrated by the experts in sensorial analysis.

NIR reflectance has been successfully used for the estimation of chemical substances or groups, in solid products. The main and well-known application for many years has been the estimation of moisture in grain; more recently, NIR reflectance instruments are used to determine protein in animal feed, or different components in flour, for example. The application of NIR reflectance to intact fruits is more recent. In a ...-years ago finished European project, researchers applied the NIR spectrum directly onto the fruits (apples and peaches) using optical fiber bundles on its surface. Sugar (measured as soluble solids) was able to be assessed with an accuracy of ± 3 ºBrix, in a few seconds. Today, the technique has been improved, and a new cooperation exists where, together with other sensors, the technique is being developed into an on-line system.

The next and most active (and controversial) instrument development concerns the *aromas*. Aromatic compounds in fruits and vegetables is an un-explored universe. As an example, in apples, more than 350 aromatic compounds have been characterised, which add to the aromatic composition, either sensed by the consumers, in the different varieties, ripeness stages, etc. or analysed chemically (by GC, gas-cromatography). Moreover, most of those compounds appear in parts per billion (ppb) on the headspace of the fruits; moreover, some of them are mixed at much higher concentrations (up to 1 million times higher); and above all this: human perception is independent of actual concentration of the gas. It is today impossible for any research group to prove that aroma in fruits can be reliably sensed by the so-called *"electronic noses"*. These are composed by an array of sensors which give an unspecific response to the different aromatic compounds. Todays' research objectives are in the line of identifying "indicator" signals, or specific compounds that can be traced reliably by the sensor(s) and relate them to a selected property one might be interested in: mainly, in the case of fruits, a comprehensive "quality", or the presence of some detrimental gases like, for example, alcohol in anaerobic storage problems, or hopefully, some

diseases. *Micro-chromatographs* are used in some laboratories for fast (20s/sample) ethylene determination, the hormone which indicates the physiological stage of the fruits, the time for optimal consumption. Also oxygen consumption and CO_2 production can be reliably measured and monitored in close chambers, as it is done very generally in fruit storage facilities.

6. How to evaluate the performance of the instrumentation - Metrology and standards

As it is well known, Metrology is the science devoted to the evaluation and quantification of the level of error of an instrument. Various aspects are relevant in the response of an instrument:

- *sensitivity*: the ability of an instrument to react to a stimulus defined as the slope response/stimulus. For digital instruments there is a step-like response for increasing stimulus. In these cases the knowledge on the resolution (height of the step) is fundamental as it refers to the range of response where no differences can be stated;
- *specificity*: it indicates the selectivity with respect to stimuli which might come from the sample, different from the one to be measured. (For example, if we want to measure firmness, it is important the instrument is not affected by other factors as the turgor or dehydration of the sample);
- *precision*: is the repeatability, stated as standard deviation or coefficient of variation of a measurement taken on a reference sample under identical conditions;
- *accuracy*: the degree of approximation of a measurement to a true value of the correspondent magnitude. It implies the existence of a reference of known true value (certified reference material);
- *reproducibility*: the degree of approximation of a pool of measurements of a certain magnitude measured with different methods, instruments, operators or conditions (temperature, relative humidity) [10].

These metrological parameters refer to the instrument, they do not include the sampling variability, which in the case of fresh produce is usually very high, between- as well as within individual specimens (i.e. soluble solids content of peaches).

In most of the quality parameters reviewed here, no standard reference materials exist, to establish the accuracy of the presented instruments. An exception: chemical measurements (soluble solids, acidity, aromas), where it is easy to prepare substances to be used as reference. Colour references can be used as standards for the VIS optical instrumentation. Destructive texture parameters do not count with this possibility. In these cases, the use of very homogeneous fruit samples can be adopted to establish metrological parameters. An evaluation of the accuracy and reproducibility is given just by the many years of common use. Non-destructive contact firmness measurements can be referenced to known elasticity rubber balls for example; in these cases, they are used just as precision standards, but not as accuracy standards, as they have not yet been defined as such.

7. Quality losses due to damage during handling

It has been recently recognised that existing equipment do an important damage to most fruits. This is partly due to the reduction in the use of post-harvest fungicides following EC directives in the aim to defend the consumer. Mechanical damage: bruises, punctures, abrasions, cuts, cause a reduction in the quality of the product and are the door to the entrance of rots. Only very modern handling lines, which have been intensively studied in their design and, more important, in their installation and control, cause just a bearable damage to most products. Susceptibility of each species and variety of fruit and vegetable, and in relation to environmental conditions, is a needed subject to study. Damage is the addition of high

susceptibility of the product plus harming effect of the machine. Fresh market products are manually harvested, as it is obvious that damage would be too high with the present fruit-harvesting machinery, but on the other hand, no sufficient attention has been given to post-harvest equipment.

Some years ago [11] the electronic fruits were developed, with which it is possible to assess critical "damaging" points in the handling lines and the whole process of fruit harvesting and post-harvest. Using those instruments, and the appropriate software, it is possible to establish precise improvement measures to reduce damage to a minimum. The knowledge attained so far has allowed to develop a first tool, consisting of a user's program, in which a data base on fruit characteristics is combined with the data base of the equipment damage potential in its different elements, so that an estimation of the percentage of damaged fruit, in the whole machine, and in each of the "critical points" can be made, to help in the decision of improving the handling line or diverting the fruit load according to the aexpected quality [12]. A similar simulation program has been developed recently for sugar beet harvesting and handling.

8. Sensor fusion and automation of information systems

From the brief summary presented here on quality measuring instrumentation, it is evident that many different sensors and instruments exist, which can be used to evaluate different quality aspects of fruits and vegetables. Every product will have its own pertinent quality factors, with the corresponding magnitudes and tests, the results of which will be combined in appropriate protocols. In a near future we will have some of those sensors mounted on-line, it may be in the commercial handling lines, for complete fruit-by fruit measurement, or much sooner, in automatic sampling lines for grading the average quality of every load, and its variability. Two aspects are related to this development: one is the interest of combining the information for various different sensors for decision purposes, called "sensor fusion"; the second, is the clear need for automate quality laboratories and merging of data.

A first result of the installation of an increasing number of sensors on-line will be an increase in the categorisation of many products. We may think first of how many categories can be presented to the consumer. In this sense, it has been proposed that a hierarchical integration of the information could be made for the different instruments' data, and provide the system to mimic the criteria of assignation of priorities made by the consumers [13].

Some instruments and sensors may eventually yield erratic values, especially when mounted on-line. In these cases, one should establish ranges of validity of the results, so that the system can automatically reject those erratic values. A second possibility is to evaluate the degree of accordance between the results given by different sensors on the same product: On the basis of previous knowledge, one can establish decision rules on expected correlation models such as, for example, between firmness and sugar content in selected apple loads; this would eliminate much erratic information. All this information systems will be needed when the on-line equipment now being developed is put into practice.

Sensor fusion is a wider-scope objective. It uses such information in complex systems, where the data from groups of sensors are compared, included its variability and range, for individuals and for batches or loads, and according to specified rules, decides upon the category of the product.

The automation of laboratories to determine quality parameters includes gathering many different sensing instruments with information systems, and has following constraints:

- sufficient replicates have to be carried out for every sampling unit and batch;
- different number of replicates are needed for different parameters to be measured;
- the instruments are very different between them, in their use, in the presentation of the samples, in the data

obtained: scalar, signals, multidimensionality;

- data have to be gathered in common databases, which have to be complete; accessible; with efficient information search; self-exploratory, user-friendly;
- decisions must be taken fast;
- many samples have to be processed per day.

All this obliges to organise the system for data which follow very sparse patterns. The design has to be developed according to the commodities and to the needs of the individual users.

9. Conclusion

We can count at present on many different sensors and instrumentation which can yield relevant information on fruit quality magnitudes.

In a very near future we will see automatic lines, provided with all kinds of sensors, which process product samples continuously at the entrance of the product into the plant. The data from the selected fruit loads will be all analysed and in the manager's computer before the load has been finished (or even started) to be processed and packed. The handling lines will be very gentle with all kind of fruits and vegetables, maybe not so fast as 10 fruits/second.

At present, a first step will be the design of centralised computer programs for data acquisition and analysis. We will rely also on information systems already at hand, which can be efficiently developed into decision aiding tools for the users.

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Table 1 - A revision of qualitative properties with an instrumental reference.

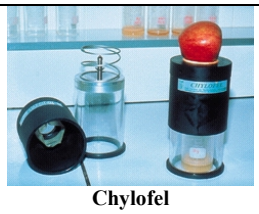
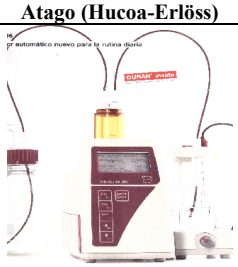
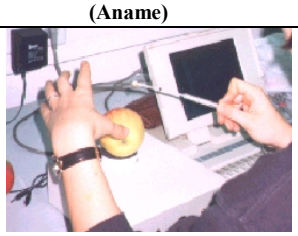
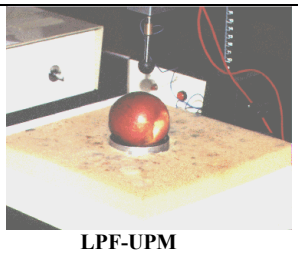
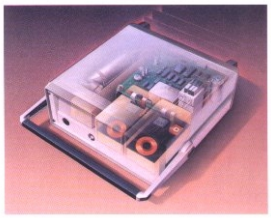
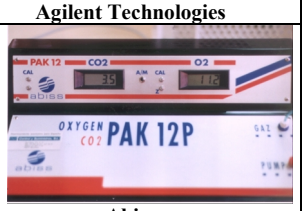
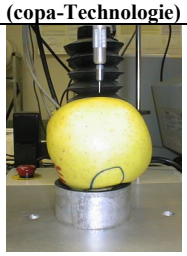
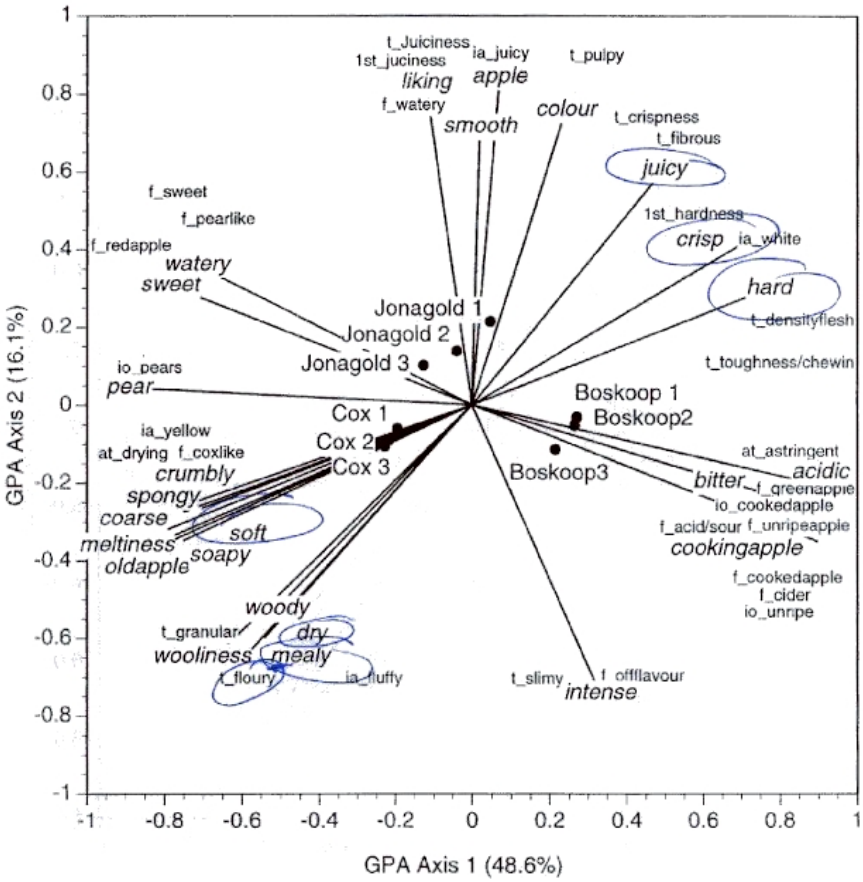
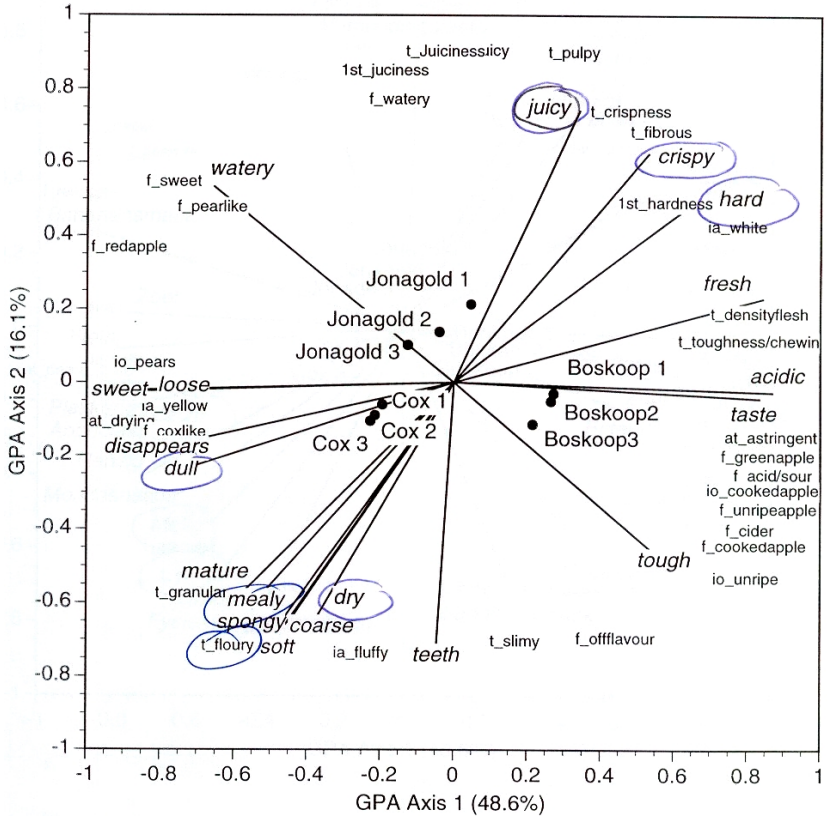
QUALITY PROPERTY *MAGNITUDE*	INSTRUMENT	QUALITY PROPERTY *MAGNITUDE*	INSTRUMENT
Colour XYZ Lab L*a*b*	 Minolta (Aquateknica)	Juiciness Chylofel chylofel units(%)	 Chylofel (Copa-Technologie)
Magness-Taylor firmness Penetration resistance (N)	 Andilog	Sweetness Soluble Solids (%)	 Atago (Hucoa-Erlöss)
Firmness on Universal Testing Machine Pen. resistance (N) Modulus of deformability (N/mm)	 Stable Micro Systems (Aname)	Acidity Titratable acidity(meq/l) or g/l of malic acid	 Schott-Geräte (Hucoa-Erlöss)
AIR firmness *stiffness* factor (hz $kg^{2/3}$)	 KU (AWETA)	Starch Iodine index (-)	 Amidometer (Copa-Technologie)
Firmness by impactometry Modulus of deformability (N/mm)	 LPF-UPM	Physiological stage Ethylene emission (nl/g h)	 Agilent Technologies
Firmness Durofel durofel units (-)	 Durofel (copa-Technologie)	Respiration CO_2 (%)vs time and space O_2 (%)	 Abiss (Control y Suministros)
Turgor state Deformation in puncture (mm)	 LPF-UPM	Aroma Aromatic emission (µmol/kg h)	 HP Agilent Technologies

Figure 1 - Projection of sensory panel means and median vectors of attribute groups from UK (1), Danish (2) and Spanish (3) consumers onto the GPA sample map from all 125 consumers [2]





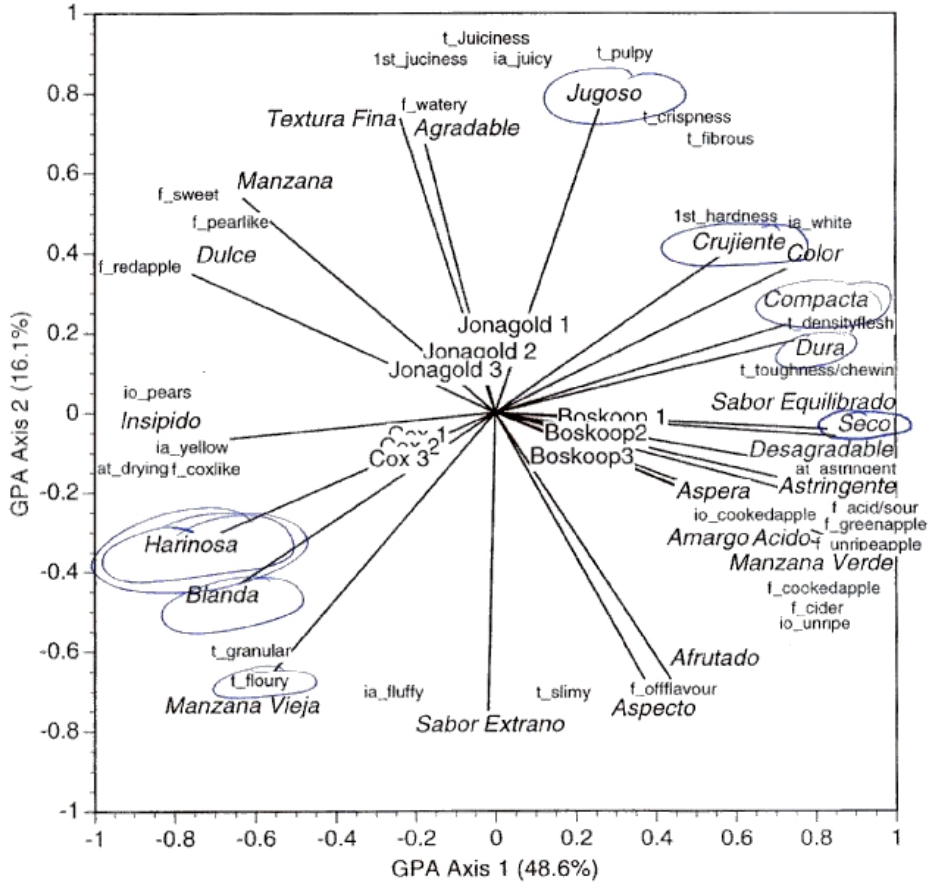


Figure 2 - Summary of the process of development of an instrument, starting from a quality property with no reference magnitude (left) or with reference magnitude (right). Feed-back is needed on some stages during the process.

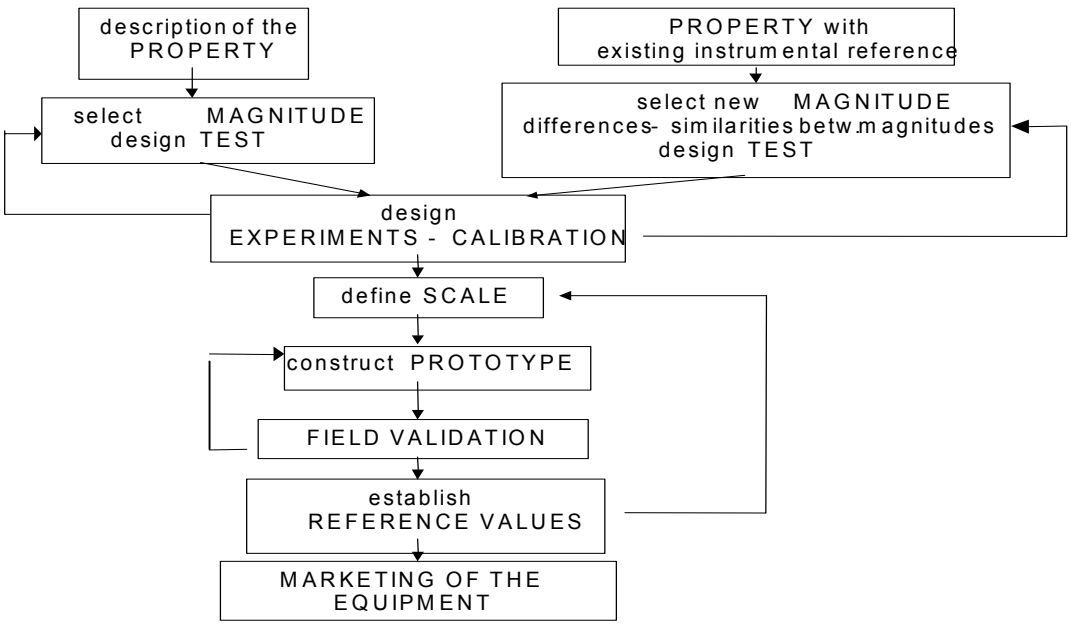
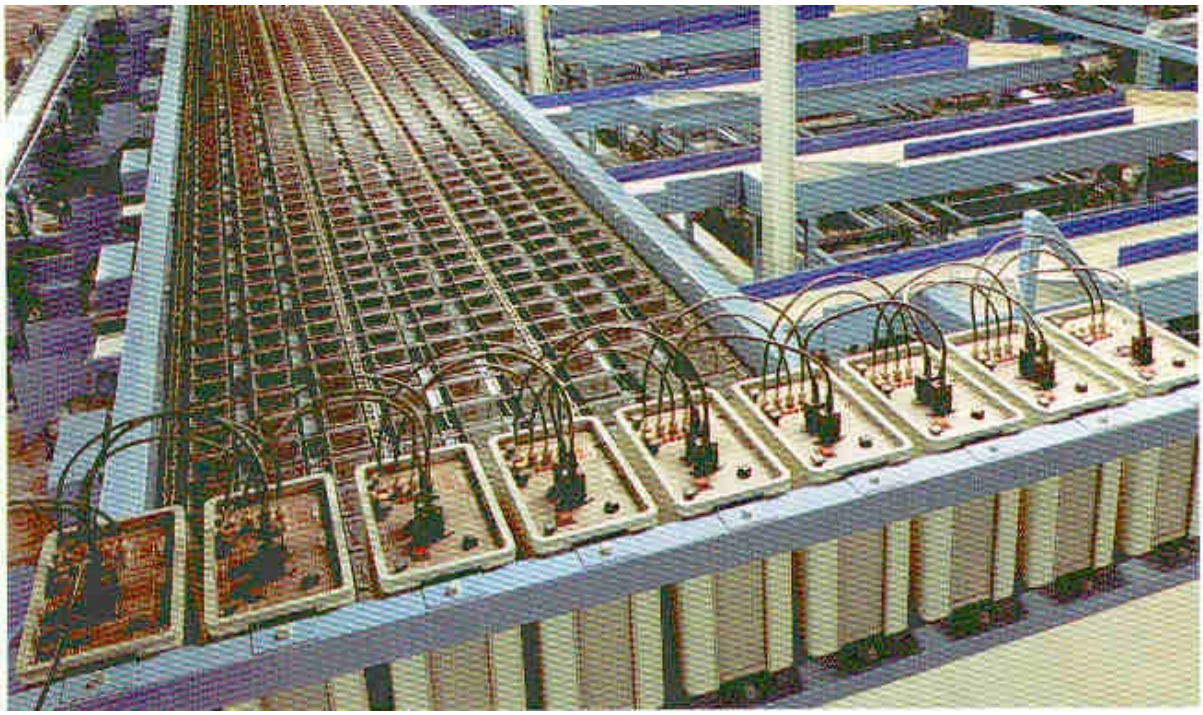


Figure 3 - Vision equipment installed on a handling line for sizing, nine fruit channels, and one full camera unit per channel (1-2 CCD)



DISCUSSION

Luigi BODRIA
The picture coming from these three presentations is very complete, we have a lot of issues to discuss and I am sure that the discussion will be stimulating.

Yoshisuke KISHIDA
JAPAN
I have a question for the three speakers. Do you thing that in the future microbes will be more connected to the human being? I mean that we will probably heat some microbes inside food. For this reason there will be a clear research of what will be dangerous or not for our health. Is this kind of research already started in Europe?

Josse DE BAERDEMAEKER
I think that this issue refers to the micro machines that good move into the intestinal system and into the digestive part. It is an interesting aspect we should not forget: nutritional value is not just the content of different components, but it is also the structure and the way it can be digested.

Anthony WYLIE
CHILE
I think that the question we have just heard is very important, because of the growing significance of food safety. The problem is to have a rapid response with the testing systems, for determing, which bacteria, or microbes are on the food. I've got two different impressions from this very interesting and complex subject: one is that the consumers and supermarkets don't want to pay more to have better fruits. The other is that business is good in this sector and so there is space enough for innovation. All these technologies involved very big capitals investments. The researchers, the manufacturers, the supermarkets, the consumers will be happy, but the producers will disappear because of the big costs.

Josse DE BAERDEMAEKER
As related to the second part of your question, I can say that in Belgium we found that the supermarkets will not pay more for improve quality till there will be no possibility to clearly distinguish these certified products from their competitors. I think we will still have farmers, producers, etc. It is a circle: those who can delivery good quality products with the prices imposed by the market will survive, probably in the end there will be few of them and these last one will make more money. Mr. Kishida, concerning your question of detection of microorganisms, I know there are some methods but they require about 45 hours and it is too slow for being introduced in the market.

Margarita RUIZ-ALTISENT
I want to add that there are also people who pay more to have biological products, so I think that there is the possibility of getting more money in some parts of the market. Secondly, I think that right now there is a lot of hand labour used and the substitution of this labour will be uneconomic even with high-tech equipments. In relation to bacteria problem inside food, I can just repeat what Prof. De Baerdemaeker said before, it is impossible to certify that every single apple has or not some residue on it, for me it is a matter of production system control rather than of looking fruit by fruit.

Jürgen ZASKE
What I feel is that we can't prevent technical progress. After you have introduced new technical ideas I think the market will reach again a balance; it is very similar to science and environmental protection. If you detect substances, which may pollute, very soon the legislation will consider them. It means that we have to remember that things developed by science can become of public use.

Ali Mahamoud EL HOSSARY
EGYPT
I will speak again about the food safety. Sometime we export some fruits and vegetables and they are rejected after 15 days.

Josse DE BAERDEMAEKER
The same happens in Europe: you export something to another country ant two days later it comes back. I think the best will be to change the practices: your customers, or clients will insist that you register all the pesticides you have used, to have more controls. In some cases we have controls before harvesting, people check in the laboratory and if the level are too high you haven't the permission to harvest, may be you have to wait an other week.

Uri PEIPER
ISRAEL
Every day the majority of farmer products are sold to the consumers by the big supermarkets. They are more interested in the quality of the food, in two aspects. First of all the marketability - that means the appearance of the fruit for the consumer - and, secondly, the safety of the food, that seems to be the major factor.

Jaime ORTIZ-CAÑAVATE
SPAIN
My impression is that we had three very good presentations. The most important problem concerns damages produced by mechanical handling of the fruit; when you have the fruit on the tree normally quality is excellent, but later when it is handled it is damaged. We have discussed about the possibility to have some implements, or instrumentations to detect these damages, in order to separate these fruits from the other. May be we have also to look for some varieties that could resist to this mechanical handling. This is the same as happened with the tomatoes in the past: in principle the tomatoes harvesters couldn't harvester

available varieties, later on with the co-operation of the plant breeders these tomatoes could be harvested mechanically. I want to ask to the three speakers what is their impression in co-operating with plant breeders, in order to have varieties that could be resistant to damages.

Margarita RUIZ-ALTISENT
The point is that it is much more difficult to improve tree crop than plant crop, secondly may be that some treatments could decrease the susceptibilities of the fruit it-self to be handled. In this case there's a lot to do with the management of temperature and moisture. For example, there are fruits that can resist much better than other; this is something well known, but not enough introduced into the management of the handling, it can improve a lot the resistance of the products.

Jürgen ZASKE
The problem is that the consumers and the producers have different expectations and it is quite difficult to match both parts. Nevertheless I think that improving the production line is still a task for the future. Even in that case it may be possible to use the attractive methods for optimizing the production line, while on the other hand the control of production must be of course an automated process.

Ladislav NOZDROVICKY
SLOVAK REPUBLIC
In the last 10-12 years the vegetable and fruit growth was more concentrated in large state farms; import of fresh fruit or vegetable was very limited and a large amount was not always present in the supermarket. After ten years the situation has changed. There are some positive effects: fresh fruits and vegetables regularly reach the market during all the year, so that the price of these products decreased in general. But there are also some negative effects. The quality of imported fruits and vegetables several times is not sufficient, domestic production of vegetable decreased and facilities for growing, storing and processing were stopped so that the machines not renewed became rapidly obsolete. In the Slovak Republic we have good soil conditions and we have reached good results thanks to the co-operation with the European Union introducing new programmes to support the domestic fruit production by different subsidies and by importing new technologies.

Margarita RUIZ-ALTISENT
Do you have any equipment for handling fruits and vegetables? If yes, which one and how many?

Ladislav NOZDROVICKY
Most part of the equipments for handling is imported, for example, from Holland, or Denmark.

Yoav SARIG
ISRAEL
Sometimes I have the feeling that we are trying to tell to the grower what quality he needs to do. We are scientists or technology developers and this is basically an issue of different interests. The consumer wants the best for its money, he wants a product with a precise quality and able to last a long. The retailers and the growers are interested in maximising the profit and in minimising the waste. So we are talking about different perceptions of quality on both sides and this will create difficulties. I disagree with Prof. Ruiz Altisent, I think the market is saturated; I'm happy for you that the Spanish industry has prosperity, but you have to wait for the Chinese market, then they will put you out of market in a second. They are already number one on apple production in the world. But not just on this, they can grow everything from tropical, to subtropical fruits. There is an issue of competition, and that's, in my opinion, the major motivation for developing in technology. For example the costumer is interested in a melon and he would like to ask to the producer to major the sugar contain of it. If we - as melon grower in Israel - we will ship to the European market a melon with sugar content guarantee - obviously more expensive, and others will give melon without sugar content guarantee, which one do you think people will buy? 85% will buy the first one with sugar content guarantee. All the technologies that we are developing now are to assure to the consumers that our products are free of defects. This is part of the complexity we have to keep in mind when we talk about technologies. It is not just a practice of quality evaluation, but it is part of a system engineering approach, starting from the growing until the marketing. Consequently it is necessary to focus on those instrumentations and techniques, which have the priority. It doesn't surprise me the fact that we are in the same position as 7 years ago when we discussed first this topic, because nobody was ready at that time. It is not only a matter of not available technology, because having the money to pay for, we would have all these technologies. For this reason we should have priorities in order to give to the consumers something enough for his money.

Jürgen ZASKE
If you consider the national economies, or the economy of the European Union as a whole you have to feel responsible also for the other countries and not only for the consumers. What we are doing more or less is offering solutions for specific questions, that's the task of science. It is not our task to design and have integrative approach, this is more linked to the producers them-selves to get the idea that may be developed by scientists, institutes and compose it in a way to optimise the profit. It's very normal because: the producers want to get money and if they have competitors they look for other solutions, which could make the products profitable again. The integration is more or less a task of the whole economy. I have the tendency not only to look at what is getting to the consumer, but also to who can make profit on the basis of scientific developments.

Yoav SARIG
Usually everybody make profit except for the growers, that's the worldwide situation and you have to agree with me.

Jürgen ZASKE
Ok, but imagine if a producer stops production of perishables towards the production of something else; I think this will not last long, because even in the centre of Europe there is not the tendency to import everything from everywhere except from the surrounding countries. So I thing there will be always a tendency to have a balance production in agricultural production. For example, the producers of centre Europe, or of Israel, have access to the whole market of machineries, of testing equipments and so on, and they will optimize their production; the other countries that don't have the money and the instruments to do so, have other peculiar capacities that make them profitable in the market too, like Morocco which is a strong competitor of Spain. I think there is a different situation world-wide, but there is still a change for the producers to make profit under different conditions.

Josse DE BAERDEMAEKER
I have some additional comments on Sarig's statement. We talk about chain management from producers to the consumer, but we have to consider that there is something, in this chain, that is very dynamic: products are not constant over the time, they change their properties. For example considering transportation distances, sometimes fruits and vegetables are harvested when they are not very good in quality; if you pick an apple later from the tree, it will probably be tasteful than one you have picked earlier; but if you want to keep apples for 5-6 months in storage you have to take them earlier. In the northern part of Europe we have peaches very early in the market, they are picked at a very immature state because of a pressure on the market: consumer wants to have peaches all the year, he pushes the market to find peaches somewhere. May be other people having comments on that.

Antonio PAGANI
ITALY
I sincerely want to congratulate with you, because I learned a lot from the excellent presentations. I'm not very familiar on this topic so may be my comments will be not exactly. It seams to me that in a way the three presentations convey a common message, which is that standards, in this particular case, are not fixed, but set by the consumer. What I can - as a consumer - consider of good quality, may be intrinsically not of good quality, even if it may satisfy my expectations in terms of shape, colour, smell etc. In the end I really don't know its nutrient power, health content etc. We talked a lot about apples, let's talk a second about banana. Who of us never came across the famous blue label banana? My wife goes to the supermarket and buy bananas and probably for her it must be that banana, of that size, colour, and shape. But I'm not perfectly sure that it is the top quality banana in the world. In this field the approach to a standard quality definition should be more in line with other scientific sectors, rather than leaving so much power on the consumer side, who, in my opinion, may be not correctly equipped to judge the quality. His decisions come from impressions, marketing action, pressure on the market, publicity and TV.

Josse DE BAERDEMAEKER
I think you raised an interesting problem. Are we giving something that the consumers really like, or are we giving something that the consumers should like. If you compare the advertising budget of Coca Cola and the advertising budget of fruits and vegetables industry you'll be surprised on the amount of money that Coca-Cola invests in its advertising campaign. The result is that this industry can really manipulate the expectations of consumers. In many discussions between growers, co-operatives etc, the question always came up: how can we reach the consumer and this is a very difficult problem to solve.

Margarita RUIZ-ALTISENT
I didn't say that in our study on apples, all the consumers liked the same thing. I was saying that all the consumers preferred similarly the same characteristics: if one said this apple is sweet, or this orange is acid all consumers, at least, perceive the same thing. We know that some consumers like very sweet apples and others like sweet and acid apples, the point is that we already know that we can measure the level of sugar and we manage it. The consumer knows and pays for this. It is always something related to the products availability. We have discovered that we can measure some properties really linked to what the consume prefers.

Antonio PAGANI
I will favourable see a trend toward a stricter quality definition in terms of matching standards. The words more quality, less quality are open to million of interpretations; in other sector I know that quality is match in standard: if one thing is 1 micro taller it is not in quality. In this field it seems to me that there is still a dangerous flexibility.

Margarita RUIZ-ALTISENT
This is exactly the point we all agree on.

Jürgen ZASKE
There's a similar situation, for instance, in selling wines from Italy and Germany. Nobody knows the different makes and even the regions, but we have the definition that this wine is dry, sweet, medium and so on. Everybody can choose following his personal preferences. What I think is to establish fair trading conditions from the producer to the market and finally to the consumer. If we have fixed objectively quality definitions then we can argue much better among the different parties.

Amir U. KHAN
U.S.A.
First of all I must congratulate with the three speakers for their interesting papers. I am an outsider, because I'm an engineering designer so I don't know a lot on the subject, nevertheless I get the feeling that most part of the discussion was on developing basic information on the criteria for the various testing. Personally, I think that every fruit has different requirements for quality. Right now you – as researchers, institutes, scientists - are developing a lot of basic knowledge on everything, but is there someone going to apply this knowledge following priority factors.

Josse DE BAERDEMAEKER
If you look at the work done you can see that the basic technology was developed probably 10 years ago, but at that time when you talked to machinery manufacturer there was no problem. They didn't have a fruit market and they didn't feel the pressure. Now a day it seems that it hasn't changed, because customers in general and the customers of the packinghouses of distribution, apparently are trying to impose some requirements in terms of fairness. In this way all come back to the fruits producers and to those who produce the equipments. Basically it isn't always a scientific problem to bring a product to the market, but it is just a marketing problem linked to the quality aspect

Amir U. KHAN
What you are saying is that we will develop all the basic criteria and then let things go to the right place. It was said that in 7 years not much has changed on this topic and that's the issue I want the speakers consider, because may be there is a gap in the research applied, perhaps some institutions could focus on the apples cultivation, for instance, and consider all the problems, even evaluate the customer as well as the packaged needs and so on. I think that without priorities it will take long time to see precise results.

Josse DE BAERDEMAEKER
I think that priorities come from the market side.

Jürgen ZASKE
It is always a problem to turn new ideas, or new developments into practice. Every time when an institute is developing a prototype it is difficult to market it. Everybody of us knows how useful it is to have closed relations with the producer and to develop a prototype together with the interested industry in general. Normally we don't develop a real prototype, but a mechanical instrument showing specific functions. I have talked about the spectral analyser used to define the chlorophyll content, which gives information about the rightness of an apple, for example. If you install this instrument on some kind of manipulator, you can measure the fruit state, so that in the beginning you have measured objectively.

Margarita RUIZ-ALTISENT
Talking about equipment, I know that there is somebody here from the equipment manufacturers, who may be very interested on the case. Can he give us an idea?

Luca MONTANARI
UNITECH - ITALY
I think that, as manufacturers, we are in the condition to put money on the research, to develop instruments able to satisfy the new requirements. We are in a crucial moment now: in the past there were so many technologies useful to detect the quality of the fruits, so that we were quite disappointed, we didn't know exactly where to go on and now after 10 years of researches we are all waiting for some results because we believe that the application of the vision system may be considered as a reality. We have to keep in mind that for the packinghouses the most important factor is to reduce costs. They want a type of machine, which selects the external defects, that allows them to have few people packing the fruits. The second step is linked to the internal quality and here the situation is quite difficult, because we are all testing different ways.

Yoav SARIG
I want to emphasise again the role of the consumers. Let me give you an example about the discrepancy between the quality evaluations of the industry versus that of the consumer. You probably heard about a study on tomatoes cultivation. The producer is interested in extending the production line, he is interested to maximise his profits by having a tomatoes, which lasts not for two days but for 6 months. Obviously in this process the product lost the taste and the producer has to face to the dilemma: tasteless or more profitable. It takes time but the consumer will come back to the producer and says: "We don't want that", and if the consumer doesn't accept what you produce, you can have everything but no-one will buy. Considering the example of Coca-Cola: some years ago this industry tried to introduce another product into the market, putting a lot of money. The consumers didn't like it and then it has been taken out of the market. The consumer has the final word and we have to follow him. I think that, in spite of what was said, we made lots of progresses. If the consumer doesn't demand there is no need: if the consumer doesn't demand something guarantee, the industry says: " I'm not interested in what manufacturers are developing in this field". For me it is good that the progress continues and the scientists provide technologies even if they are not immediately used; it is not a matter of research it is a matter of readiness of the market to accept technologies available.

Jürgen ZASKE
I think you are completely right, but this is a different discipline: it is a marketing aspect and this is not our profession.

Josse DE BAERDEMAEKER
I just want to add something about quality standards, because of the question of Mr. Pagani concerning precise quality standards. I remember, a couple of years ago, we had a cold winter and all the cauliflowers were frozen in Europe. In that occasion we saw how you can stretch your quality standards. In normal conditions the cauliflowers available will not be accepted by the market, but in that occasion they were ok. So quality standards are flexible, they move closed to what is available on the market.

Antonio PAGANI
I have still difficulties in understanding this continuous tie among standards, market, and the receptiveness of the customer, this is another thing. If I have three standards levels and due to seasonal problems I can't reach number one and two, but just the number three the market will have just the number three. In my opinion this is something different from what the customers or the clients can prefer. I am not saying that we shouldn't take into account the taste and the preferences of the final buyers, but standards are another thing. For instance, if you consider the typical example of vehicles: Mercedes and Alfa Romeo quality standards are different, I'm not saying that one is better than one other, but you – as client – you can prefer one to another. At the end quality is one thing and clients preferences are something else.

Josse DE BAERDEMAEKER
I think it is good to separate. We made a lot of studies on quality standards even for standards used by private organisations and we found that some products can be classified in different classes at the same time. It seems to be very difficult to keep up the rules we have.

Luigi BODRIA
I have the impression that we have underestimated the problem, because we thought that with three qualified speakers in half a day we could discuss and reach some conclusions, but it is a hard job. The quality we have on field must be preserved and must arrive to the final consumers, through a long way. We don't know exactly which are the standards of references, because we have a very large panorama of parameters.
My feeling is that up to now we don't know exactly which one could be the more convenient to reach some practical results.

Margarita RUIZ-ALTISENT
I can't agree with that. Many companies are now developing and installing some of those techniques. Nowadays things are growing very fast.

Uri PEIPER
I think one of the problems is that we try to quantify quality, which is a very difficult job to do. The quality is something which changes: a product-classified class A for me, in an other country will be not necessary classified at the same place and we have to take into account this. To talk about a unique quality standard which will be applied for the most part of the products is something that can't become reality.

Pavel KIC
CZEK REPUBLIC
I want to say something on how to prepare new generation to the question of quality. The quality of agricultural materials and physical properties is a material we studied for many years in our faculty. 10 years ago we prepared a new studies programme for our students, as for example on cultivation, or mechanisation for harvesting and post harvesting processes, transport and logistic system. Up to now we had good results thanks to this application.

Luigi BODRIA
We arrived at the end of our session. I thank our three speakers for their excellent presentations and all the participants and I give the floor to Prof. Pellizzi.

Giuseppe PELLIZZI
Ladies and Gentlemen I think we had a good discussion, with a lot of interventions. Many problems are open to be solved. I kindly ask you to read the draft Conclusions and Recommendations we gave you and to supply your comments. Let me also draw your attention to the short guidelines prepared on the subject discussed last year in Bologna on the "Technology Transfer in Developing Countries". Please, have a look at them and send to the Technical Secretariat your comments and suggestions Thanks you once again, with the hope to see you in Tsukuba.

LIST OF PARTICIPANTS

Giuseppe Pellizzi	ITALY	*President of the Club*
Ali Mahmoud El Hossary	EGYPT	*M.C. Member*
Karl Renius	GERMANY	*M.C. Member*
Uri Peiper	ISRAEL	*M.C. Member*
Carlo Ambrogi	ITALY	*M.C. Member*
Pietro Piccarolo	ITALY	*M.C. Member*
Bassam Snobar	JORDAN	*M.C. Member*
Arturo Lara Lopez	MEXICO	*M.C. Member*
Jan Pawlak	POLAND	*M.C. Member*
Derek Sutton	UK	*M.C. Member*
Rainer Ramharter	AUSTRIA	*Full Member*
Anthony Wylie	CHILE	*Full Member*
Pavel Kic	CZECK REPUBLIC	*Full Member*
Peter Schulze Lammers	GERMANY	*Full Member*
Jean Gilles	GERMANY	*Full Member*
Yoav Sarig	ISRAEL	*Full Member*
Luigi Bodria	ITALY	*Full Member*
Paolo Celli	ITALY	*Full Member*
Antonio Pagani	ITALY	*Full Member*
Yoshisuke Kishida	JAPAN	*Full Member*
Michael Faborode	NIGERIA	*Full Member*
Masood Ahmad	PAKISTAN	*Full Member*
Ion Pirna	ROMANIA	*Full Member*
Ladislav Nozdrovicky	SLOVAK REPUBLIC	*Full Member*
Jaime Ortiz-Canavate	SPAIN	*Full Member*
Amir U. Khan	USA	*Full Member*
Milan Martinov	YUGOSLAVIA	*Full Member*
Mario Pedro Bogliani	ARGENTINA	*Invited*
Josse De Baerdemaeker	BELGIUM	*Key Note Speaker*
Jurgen Zaske	GERMANY	*Key Note Speaker*
Margarita Ruiz	SPAIN	*Key Note Speaker*
Gualtiero Baraldi	ITALY	*Associate Member*
Franco Sangiorgi	ITALY	*Associate Member*
Marco Fiala	ITALY	*Technical Secretary*
Saurgnani raffaella	ITALY	*Technical Secreteriat*

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