DESIGN GUIDELINES FOR A QUALITY ASSESSMENT SYSTEM OF FRESH FRUITS IN FRUIT CENTERS AND HYPERMARKETS

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ABSTRACT

When the fresh fruit reaches the final markets from the suppliers, its quality is not always as good as it should, either because it has been mishandled during transportation or because it lacks an adequate quality control at the producer level, before being shipped. This is why it is necessary for the final markets to establish their own quality assessment system if they want to ensure to their customers the quality they want to sell. In this work, commissioned by a multinational hypermarket enterprise, a system to control fruit quality at the last level of the distribution channel has been designed, after gathering information about the movement of commodities inside company and its requirements. The system combines rapid control techniques with laboratory equipment and statistical sampling protocols, to obtain a dynamic, objective process, which can substitute advantageously the quality control inspections carried out visually by human experts at the reception platform of most trade centers as the one studied. Portable measuring equipment have been chosen (firmness tester, temperature and humidity sensors...) as well as easy-to-use laboratory equipment (texturometer, colorimeter, refractometer...) combining them to control the most important fruit quality parameters (firmness, color, sugars, acids). A complete computer network has been outlined to control all the processes and store the collected data in real time, and to perform the computations. The sampling methods have been also defined to guarantee the confidence of the results. Some of the advantages of a quality assessment system as the proposed one are: the minimization of human subjectivity, the ability to use modern measuring techniques, and the possibility of using

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it also as a supplier's quality control system. It can be also a way to clarify the quality limits of fruits among members of the commercial channel, as well as the first step in the standardization of quality control procedures.

Keywords: equipment, laboratory, physical properties, organoleptic, technological transfer

INTRODUCTION AND OBJECTIVES

During the commercialization of fresh fruits, the quality of the product can be deteriorated at several points of the marketing channel. One of these critical points is the stage in which the fruit comes out of the producer facilities (quality-controlled or not) and reaches the wholesaler chambers. The product may arrive at the storage in very different conditions that those observed at the field or the packaging lines, due to bad control of the climatic conditions in the trucks or to impacts and bruises during handling and packing.

Even if the fruit is not damaged during transportation, its ripeness level will have changed more or less during this period of time, and the wholesaler must know the details of this maturity evolution to decide how and when to sale each batch of product. This is why a quality assessment system is needed by the hypermarkets and similar fruit trading centers, to ensure themselves that the fruit they are buying posses enough quality, as well as to guarantee it to their customers.

Along the past years, destructive and non-destructive measurement of fruit quality has been a primary and widely established research objective (Abbott *et al.*1997). Many different techniques have been developed and applied to create sensors to measure quality parameters, as well as the subsequent mathematical models to predict quality evolution. Firmness and texture, besides the penetrometry and a wide variety of destructive tests, can be now estimated non destructively by means of low mass impacts (Chen *et al.*1996), acoustic properties (Armstrong *et al.*1990), microdeformation of the surface or other applications of vibration, density, rheology and electrical properties (De Baerdemaeker *et al.* 1997). Chemical contents inside the fruits (i.e. sugars, acids) can be measured from the outside by means of the optical properties of the samples and the interaction between radiation and matter, specially in the infrared, which have been proven useful in many research labs (Bellon *et al.* 1993; Gunasekaran *et al.* 1985; Kawano 1994). The color co-ordinates are quantified commonly with standard VIS spectrophotometers. Internal defects and diseases are detected on untouched fruits using combinations of penetrating electromagnetic fields (X rays, nuclear magnetic resonance) and image analysis techniques. Even more complex quality components, as aroma and pesticide residues, are being studied now and new prototypes for their fast quantification will be developed in a few years.

Many of these techniques and devices -in many cases the non-destructive ones- are based on high-tech systems (expensive) or are just not enough evolved to make them user-ready. Nevertheless there are adequate systems which can be applied directly by the marketer, commercially available and easy to use, to measure how good their fruits are by estimating the main fruit quality parameters: firmness, color, and contents in acids and sugars. There is a need in the agrofood industry for technology transfer from the fruit quality research labs to the producer/marketer. Ready-to-use measuring techniques should be chosen and implemented in the industry to help them to better control the processes and the fruit quality. Other trials have been made to provide easy systems to measure quality, as the French compact machine called “Pimprenelle”.

The aim of this work was to review the state of the art in fruit quality assessment and measuring devices, transferring the scientific knowledge to the marketing channel at the level of full applicability by the marketer. Thus, this work is a practical proposal to a wholesaler: a system to measure the quality of his fruits with equipments as simple as possible, and the design of a working process to get the best use of the acquired information as much as possible.

METHODOLOGY

This study was commissioned by an important multinational company of hypermarkets, with more than 25 establishments in the main cities of Spain. The distribution structure of this company, concerning fruits and vegetables, is centralized in one facility called ‘Docking Platform’, where all the fresh fruit and vegetables arrive to and are forwarded afterwards to the sale points. The platform has 12 docks where the trucks from the producers unload their shipments during the night. Although there are two cold storage chambers inside the building, most of the product is immediately sorted and redistributed to conform the deliveries requested by each hypermarket on the previous day.

To design this proposal of a quality control system, a close co-operation was established among engineers from the Universidad Politécnica de Madrid and the personnel at the docking platform, at the outskirts of Madrid. Along several months the activity at the platform was studied: daily movement of product stocks, incoming deliveries and redistributed facilities was supervised during the working period (3 am – 12 am). Statistical data about the amounts of shipments of each vegetal species, variety, origin and package conformation was registered, as well as the results of the existing quality control (proportion of inspected facilities, number of rejections, causes, quantity and types of loses, etc.). A development and engineering work was carried out to achieve the objectives, based on the bibliographic review, and different practical approaches to quality assessment (Alavoine et al.1982; Planton, 1996; Kader, 1992; Ruiz Altisent et al. 1996a, 1996b).

RESULTS

The company: present state of quality control

The following conclusions were extracted from the recorded information at the platform:

- More than 60% of the product received each day is shipped again to the sale points on the same day, and the rest stays at the storage site less than 48 hours: the product at the platform gets move constantly.
- The conformation of the shipments that must be departed to the sale points is completed in less than three hours: the time available to perform quality controls is very short, since the obtained information is going to be used to help the marketing decision system.
- The present 'quality control' is merely subjective, performed by only one person that inspects one batch out of each truck, taking a bare look at the upper layer of fruits and touching the ones that could be seen from the sides without extracting the boxes.
- There is no real use of quality standards such as color tables or damage references, although the company has written guidelines to control fruit quality. No measurement equipment is used neither.
- Except for the weight of the entire batch, no record of the incoming product quality is taken.
- Each pallet of product, nor a sample of each, are never inspected
- Based on this human inspection, the decision of rejecting each batch of pallets, sending them closer or further, or storing them is taken.

As it can be seen, the actual situation at the docking platform lacks of a rigorous quality control system, and this situation is the rule at many hypermarkets and fruit trading centers. A new fruit quality control system must be defined which can cover the following objectives:

- A quality control laboratory, designed to be constructed at the platform to control the product in real time.

- An objective process based on a systematic protocol, measurement equipments and a few lab technicians to perform a good control.
- A process designed to run as fast as needed to produce useful information for the fruit transferred every day.
- The process should be able to characterize every pallet coming into the platform, to provide useful information about its ripeness level and to aid the marketing decisions that will be taken immediately.

All the quality tests and inspections should be controlled by mean of computers, which will be responsible for the storage of the gathered data.

Proposal for quality control: two control processes

Taking in mind the previous objectives and the restriction of requiring the lowest investment as possible, the following quality control system was designed: as the technologies available nowadays to be used out of a scientific laboratory to measure fruit quality parameters are either slow, expensive or destructive, it has been planned a control process based on a sampling protocol, and divided into *two sub-processes* with different operation patterns and different equipment. Each one is focused to solve different objectives, although both are complementary, as it will be explained. Figure 1 shows a general scheme of both processes, by way of the flow of tasks and actions to be carried out.

Process 1: Immediate Control During Reception Of Commodities

It will be performed by two people while the pallets are being unloaded and weighted out of the truck. It must be a fast process which combines the comparison with quality standards, with the use of small, portable measurement devices. Two people will take from two to five minutes to perform the immediate control of one pallet during its reception. The parameters that are going to be controlled at this first stage are: level of firmness, color, external damages, temperature of the fruits and relative humidity of the air surrounding the product, which may affect the internal turgidity and, thus, the shelf life and the final quality.

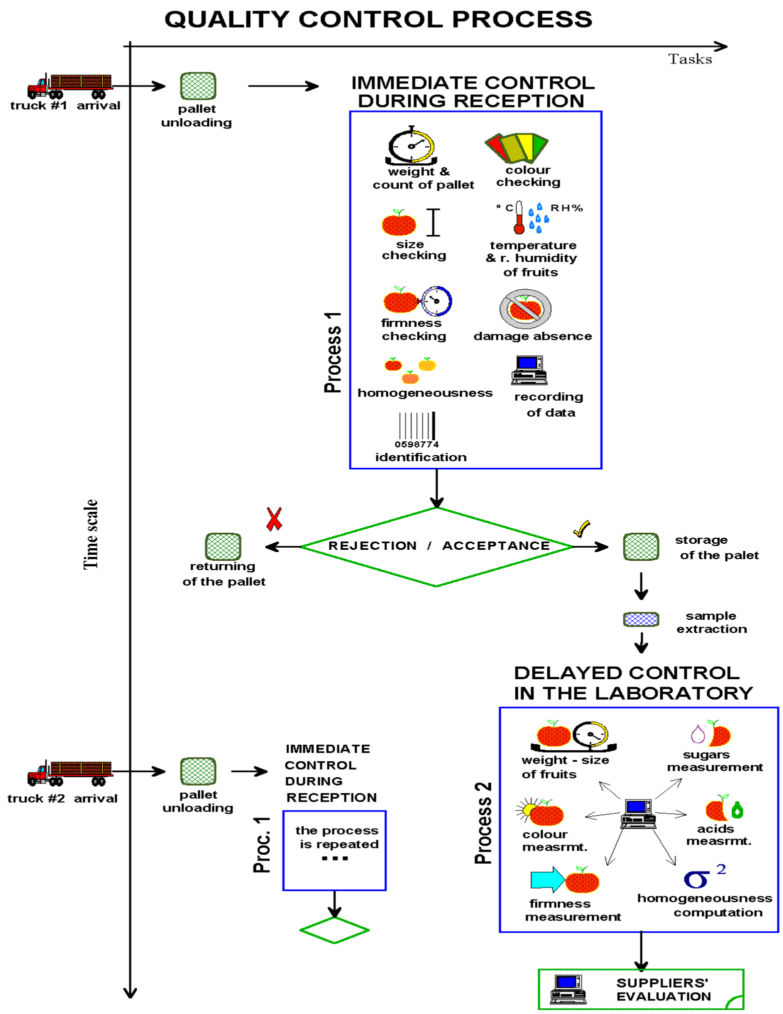

Figure 1. General overview of the designed quality control process. The sequence of tasks and decisions to be taken during the unloading of commodities is shown.

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The equipment used to determine these quality parameters in Process 1 will be:

- To measure firmness: a Magness-Taylor penetrometer to be applied on hard fruits (apple, e.g.); for soft fruits (peach, tomatoes) a "durometer" device (such as the 'Durofel' or similar) can be used, with the advantage of being non destructive.
- To measure temperature and humidity of air, a digital thermometer and a relative humidity probe will be used, with infrared non-destructive sensor if possible.
- To verify the color of the batches, the size and the absence of damages, the fruits will be compared with tables and standards as color charts, calibrated rings and injury patterns
- The information generated with all these tasks will be introduced in a database supported by computer, located at the product entrance. Depending on the investment that is going to be afforded, the introduction of the data (level of firmness, color, damages, temperature, humidity, weight of the pallet) can be manual (by means of a standard PC keyboard), aided by an electronic console with intuitive icon buttons, or automatic in the cases when the measuring devices could be connected directly to the computer by way of a direct link or infrared communication.
- As these data are being introduced in the computer, the database system will compare the measured levels with the requirements established by the company, giving a score to the overall quality of the pallet, which will help in the decision taking of rejecting or accepting each shipment.

The measurements will be performed on a small sample of fruits taken out from the boxes in the pallet. The number of the fruits in this sample depends on the amount of fruit in the pallet, but a number from five to ten pieces seem to be adequate as it is deducted by the application of sampling procedures (Spanish national normative for sampling: UNE 34-117-81, ISO 874) and the statistic studies and recommendations of different research institutions (CEMAGREF, CTIFL, UPM, etc.). The final size of this sample depends on the experimental error of the measurements and the variability of each quality parameter, as it will be seen later. It must be considered also that some of the measurements are destructive and the pallet can be rejected and given back to the producer, so an excessive number of pieces may be unacceptable.

The estimated time to perform process 1 is 3 min/pallet, if only one person is taking the measurements. In practice, fruit centers usually have already one person unloading the trucks that can carry out most of the work while a new employee could help in introducing data; these two people would reduce the time needed to a half. This means that, for a working period of 5 hours (as it is the case), a total of 80 pallets/day can be controlled. Therefore, the time required for the operations of Process 1 is equal to the time used at present by the company for the shipment of its commodities, generating useful information in real time. Required personnel qualification for these tasks is not high, provided that a training course on the application of the devices and standards has been given.

In the case when the pallet is finally accepted, to be able to identify it through the rest of the process, it will be marked with a sticker in which a unique bar code will be printed. This reference number will identify both the pallet and the laboratory sample tray used in Process 2. As it is coded both as a number and as a bar code, it will be easily readable with electronic devices.

Process 2: Delayed Control In The Laboratory

Once the rejection / approval decision has been taken, based on the appreciations done in Process 1, a deeper analysis can be done to characterize the product. As the pallets are being stored in the platform, redistributed or even sent to the sale points, a representative sample of each will be fully analyzed in a laboratory, built inside the platform and equipped with precise measuring devices (Fig.2). Several subjects must be discussed at this point: the sampling method, the quality parameters that are going to be measured and the equipment to do so.

Concerning to the sampling, three concepts must be defined: the sampling unit, the sampling methodology and laboratory sample. The sampling unit, this is, the minimum quantity of product considered as a whole statistical population to be sampled, will be each pallet, with fruit of the same variety and coming from the same grower. Thus, the sampling unit will be conformed by multiple boxes contained in one pallet, where the laboratory sample will be taken from.

About the sampling methodology, as this is a practical development, it has been considered to give both a initial recommendation about the number of pieces in the sample and a statistical method to adjust it to the actual needs in the future. During the first stages of operation with the quality control system, the following sampling criteria about the number of pieces to pick out of the pallets could be used (Tables 1 and 2), which is based on the current Spanish normative with minor adjustments (MAPA 1992).

Table 1. Number of pieces of the laboratory sample to be taken, depending on the number of fruits in the pallet, in the case of packed commodities.

For packed commodities (boxes, trays, bags...)	
Number of equivalent fruit pieces in the sampling unit (population size)	Number of fruits to take out
Up to 100 units (fruits)	5
From 101 to 300 u.	7
From 301 to 500 u.	9
From 501 to 1000 u.	10
More than 1000	15 (minimum)

For example, if a normal pallet contains between 500 and 1100 pieces of medium-sized fruits (apple, peach, e.g.) in boxes, an adequate laboratory sample will have 10 or 15 fruit pieces. Or, in the case of bilk commodities, out of a 490 kg pallet, a sample of max 25 kg should be extracted and measured. They should be taken randomly, from different boxes of the pallet and at different height inside it.

Table 2. Number of pieces of the laboratory sample to be taken, depending on the number of fruits in the pallet, in the case of non-packed commodities.

For bulk commodities	
Total number of fruits or weight of sampling unit (kg)	Number of fruits to take out or total weight of sample (kg)
Up to 200	7
From 201 to 500	15
From 501 to 1000	25
From 1001 to 5000	40
More than 5000	70 (minimum)

Table 3. Calculation of the sample size for the laboratory control. Assuming that the mean *m* of a quality parameter is going to be estimated with an instrumental error of *e*, the number of fruits to be measured (n) depends on the variability of the parameter (*s : std. deviation*) and the population size (*N*).

Size of laboratory sample (*n*) (Clemente and Carot, 1988)	*N* is <1000	*N* is >1000
If s is known	$n \geq \dfrac{s^2}{\dfrac{N-1}{N}\cdot\dfrac{e^2}{\left(Z_{\frac{a}{2}}\right)^2}+\dfrac{s^2}{N}}$	$n \geq \dfrac{\left(s \cdot Z_{\frac{a}{2}}\right)^2}{e^2}$
If s is unknown	$n \geq \dfrac{S'^2}{\dfrac{N-1}{N}\cdot\dfrac{e^2}{\left(t_{n-1}^{\frac{a}{2}}\right)^2}+\dfrac{S'^2}{N}}$	$n \geq \dfrac{\left(S' \cdot t_{n-1}^{\frac{a}{2}}\right)^2}{e^2}$

Notes:

- If s is unknown, the sample std. deviation (*S'*) must be measured on a smaller sample, and *n* will be estimated by iterations
- $Z_{\frac{a}{2}}$ is a random variable that verifies $P\left(Z \geq z_{\frac{a}{2}}\right)=\dfrac{a}{2}$
- $t_{n-1}^{\frac{a}{2}}$ is the value of Student distribution with *n-1* degrees of freedom and a confidence of */2*

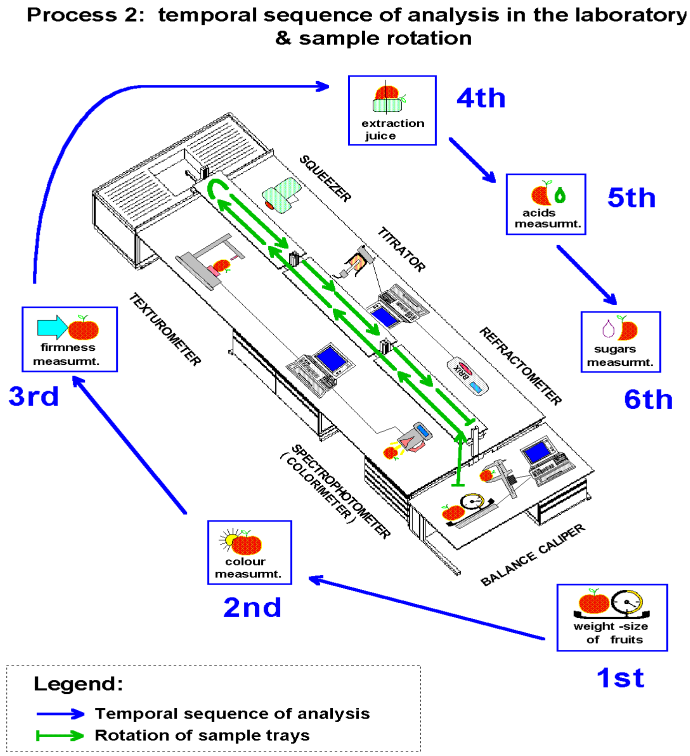

Figure 2. Process 2 of the quality control: in an adjacent laboratory the measurement of the weight, size, damages, color, firmness, acids and sugars of a sample extracted from the pallets will be performed.

Anyway, a more precise methodology based on statistical sampling methods must be used after the initial phases of the system establishment. A summary of the statistical directions to be adopted for the sample size calculation, depending on the population size and the actual variability of the parameter which is going to be measured, is referred in table 3, as proposed by Clemente and Carot (1988). The equations could be inserted in the control software system of the computer network to integrate the information of previous samples and campaigns into a database, and automatically give the most preferable size of sample, calculated for each particular case.

After the pieces of fruit have been taken out to conform a sample, they should be put into a tray, marked with the same bar code as the pallet, and given to the personnel at the quality control laboratory, next to the loading docks. Inside the lab, the next parameters will be

- Size, weight and damages: aided by an electronic balance and a caliper, both connected to a computer to store automatically the data; damages will be quantified
  camera and a image analysis software, similar to the ones used in fruit packing lines
  External color: using a portable spectrophotometer or a colorimeter (e.g. Minolta C series) connected to a computer through a interface to register -ordinates of the fruits

  doing it by itself)
  Firmness: it can be estimated performing a static Magness Taylor puncture test with a desktop texturometer (e
  directly by a computer, and programmed to carry out the test
  After measuring the firmness, the juice of the fruit must be taken out with the aid of a , and poured into coded glasses to go on with the measurements
- programmable, automatic titrator, interfaced with a computer to record the analysis in the database
- nt: measured with a electronic refractometer, also connected with a computer

To speed up the identification of sample trays, bar codes, which are placed on them when the samples were picked, will be read with a bar code reader before doing each one of above laboratory measurements. This way the computers controlling the measuring devices are notified of the sample identity that is going to be tested immediately, so they can store this system of automatic identification and storage of measurements.

The required time to rocess 2 has been estimated as 4- min/fruit. If the laboratory is going to be working 6.5 h, about 100 pieces of fruit can be proce rocess 2 operations will last more than the time used at present to ship again the commodities, but the generated information will be ready by the end of the same working day.

The personnel allocated to Process 2 have to be technically skilled. Two or three technicians (depending on the quantity of commodities to be sampled) must be allocated, one to extract the laboratory sample from the pallets, and one/two to perform the test. Although the tasks in the measurement process will be repetitive, a deeper knowledge of the devices, protocols and essays is required; then, special attention should be taken in training personnel for Process 2.

Computer network and data management guidelines

As it has been explained before, a computer network responsible for the following tasks will control all the processes:

- Help in the use or directly control all the measuring devices of the second process (laboratory) and some of the first process
- Create and maintain a database with daily information about the commodities (amount received, supplier, acceptance, quantity reshipped, identification, etc.) and about the quality of them (parameters measured in process 1 and 2)
- Automatically store the quality data as is being measured
- To provide a fast identification of commodities and their respective samples with the bar code system
- To perform calculation and analyses in the database, as statistical procedures to obtain reliable quality indexes
- To relate all the information with other databases as the acceptance quality levels established for each parameter and fruit by the company, or a provider database to control the overall quality of the suppliers

The scheme of this computer network and the devices attached to each PC is shown in figure 3. The technical specifications of the computer network are: four PCs structured into a "tree topology", wired with RJ45 cables and connectors, and interconnected and segmented using “hub” devices; the working protocol of the net is standard Ethernet, to assure ity with the existing company network.

implemented in the computer network. Nowadays, there are enough standard applications developed to perform the different tasks: connect and communicate the comp

relational database, interface with the equipments. The proposed control process may work perfectly with a traditional network operating system (i.e. MS Windows, Mac OS, Novell

and the small applications that each equipment vendor includes with their measuring devices (i.e. Texture Expert with the

Nevertheless, it would be better in the future to program a new software specifically designed

devices and measuring equipments used in the system. This will solve problems of connectivity, file sharing and direct con

in this line to gain in automation of the system.

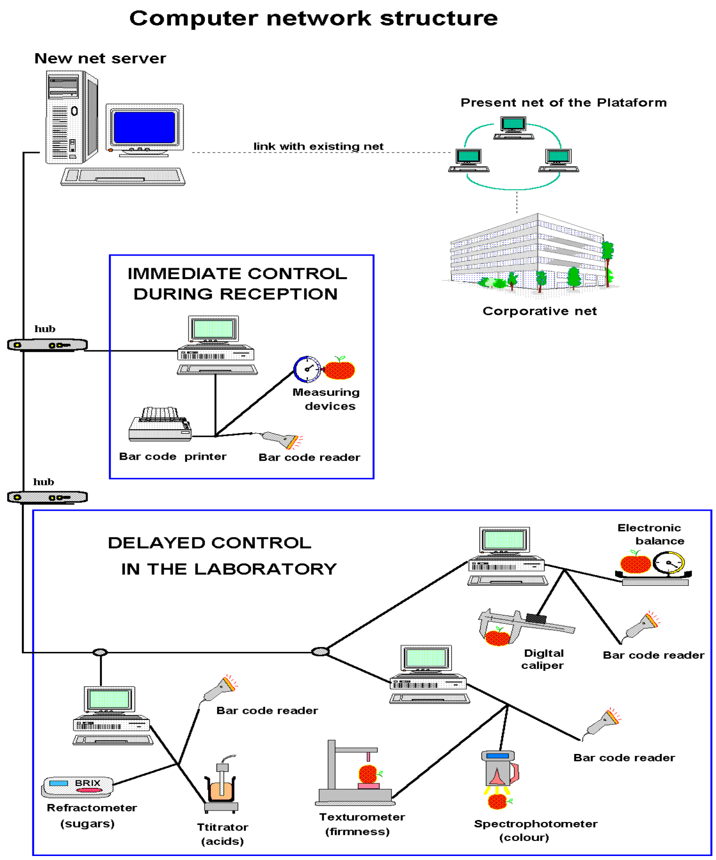

Figure 3. The whole process of quality control must be computer commanded by a network of PCs, responsible of controlling the devices, storing the measurements and maintaining a database.

DISCUSSION

Once the parameters to be controlled have been selected and the equipments chosen, one of the key factors affecting the success of the proposed system is the accurate sizing of processes and personnel. As it has been mentioned before, it depends on the amount of commodities to be controlled and on the investment that could be faced. The implementation of this control system could be done in a modular way, segmented in time. For example, a initial investment could be done to set up the process1 in a first approach, and after a period of checking and adjustment of the system, the installation of the process 2 laboratory can be completed. Another affordable approach is the implementation of the whole system but

parameter instead of all the proposed ones, and starting with the most important fruits in terms of sales. This way, the in

applied and the use of time in the processes will decrease. As an example, the following table shows several fruits and three quality parameters for each, classified by their interes measurement (Table 4).

Table 4. Recommendations about how to apply the control system gradually, measuring first the most

Type of fruit	*Parameter to measure first*		*Third parameter*
Apple	xture		Taste (sugar & acid)
Pear		Taste	Damages
	Firmness	Taste	
Apricot	Firmness		Color
Tomato		Firmness	Taste
	Sugar	Color	
Citrus fruits	Mould rots		Taste

ch a quality control system are obvious in the light of quality control standard systems:

1.

   origin of the problem, and to take measures to avoid it in the future. This is the basis

2. Market (sales) programming and monitoring: with the knowledge of the quality levels of each commodity and their evolution, marketing decisions can be taken ately as well as price policies.

   Progressive accumulation of a database to aid the decisions about fruit quality

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CONCLUSIONS

In this work, an effort to apply the scientific advances of fruit quality detection to the marketing channel has been done. The present situation at many fruit centers regarding quality control is overwhelmed by the fast movement of commodities, and the short time available to perform inspections, but also because of the insufficient use of portable devices to measure quality parameters. Although much advance has been achieved in scientific labs on sensor technology and fruit quality, there is a need of technological transfer from research to industry. The actual quality control that is being carried out in the fruit trading centers, as it has been seen in the commissioning company, is insufficient and subjective, performed basically by a visual inspection. The proposed quality control system, structured in two control processes, combines the use of selected electronic measurement devices, statistical procedures and computer aid to obtain a rigorous control of the fruit handled daily in a hypermarket of fruit center.

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