A quality assessment system for fresh fruits in hypermarkets and fruit trading centres

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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, a system to control fruit quality at the last level of the distribution channel has been designed. 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 hypermarkets. 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, colour, sugars, acids). A complete computer network has been designed 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 minimisation of human subjectivity, the ability to use modern measuring techniques, and the possibility of using 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 standardisation of quality control procedures.

Keywords : Equipment, Laboratory, Physical properties, Organoleptic

INTRODUCTION AND OBJECTIVES

During the commercialisation of fresh fruits, the quality of the product can be deteriorated at several points of the marketing channel. One of this 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

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quality assessment system is needed by the hypermarkets and similar fruit trading centres, to ensure themselves that the fruit they are buying posses enough quality, as well as to guarantee it to their customers.

Along the recent years, much research has been done in the area of fruit quality, and prediction models as well as measuring equipment have been developed to measure quality parameters. Many of them are based on high-tech systems 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, colour, and contents in acids and sugars.

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

MATERIAL AND METHODS

This study was commissioned by an important 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 centralised 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 adjust the design of the proposal of this work to the actual requirements of the company, the activity at the platform was studied by registering the income and outcome of products each night during several weeks, recording the amount of fruit received per variety, the time used to redistribute the product, the amount of product that stays at storage, the loose of product, etc. The following conclusions were extracted from the recorded information.

- 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 less than 48 hours : the product at the platform changes 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 colour tables or damage references, although the company has written guidelines to control fruit quality. No measurement equipment is used neither.
- Unless the weight of the entire batch, no record of the incoming product quality is done.
- Never is inspected each pallet of product, nor a sample of each.
- 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 centres. 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 characterise 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 .

RESULTS

Taking in mind the previous objectives and the restriction of requiring the lowest investment 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 is 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, colour, external damages, temperature of the fruits and relative humidity.

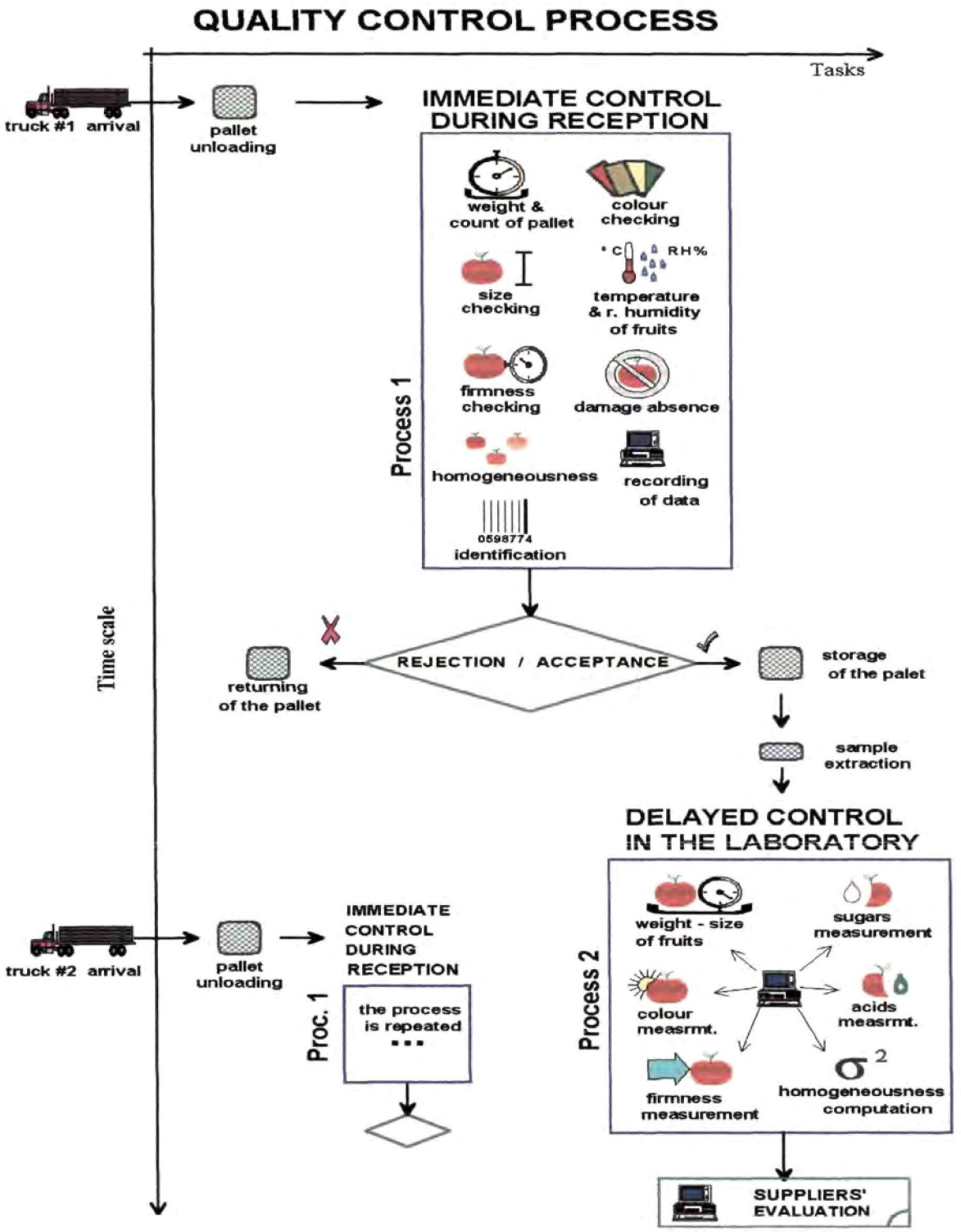

Figure 1. General overview of the designed quality control process. The sequence of tasks and decisions to be taken during the unloading of commodities is shown.

The equipment used to determine these quality parameters in the 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 humidity and temperature of the product, a relative humidity probe and a digital termometer will be used, with infrared non-destructive sensor if possible.
- to verify the colour of the batches, the size and the absence of damages, the fruits will be compared with tables and standards as colour 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, colour, 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.). 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.

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 characterise 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 analysed in a laboratory, built inside the platform and equipped with precise measuring devices. 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).

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 pieces to take out
Up to 100 units	5
From 101 to 300 u.	7
From 301 to 500 u.	9
From 501 to 1000 u.	10
More than 1000	15 (minimum)

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	
Weight of sampling unit (kg) or total number of pieces	Total weight of sample /kg) to take out or number of peices
Up to 200	7
From 201 to 500	15
From 501 to 1000	25
From 1001 to 5000	40
More than 5000	70 (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

pieces. They should be taken randomly, from different boxes of the pallet and at different height inside it. Anyway, a more precise methodology is being developed based on statistical sampling methods, to obtain equations which 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 measured, for each fruit in the sample and in the following order :

- size, weight and damages: aided by an electronic balance and a caliper, both connected to a computer to store automatically the data
- external colour : using a portable spectrophotometer or a colorimeter (e.g. Minolta C-series) connected to a computer through a interface to register the colour co-ordinates of the fruits in the sample
- firmness : it can be estimated performing a static Magness-Taylor puncture test with a desktop texturometer (e.g. Texture Analyser XT2) controlled 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 squeezer, independently for each piece of fruit, and poured into coded glasses to go on with the measurements
- acid content : measured as the total acidity of a constant volume of juice with an programmable, automatic titrator, interfaced with a computer to record the analysis in the database
- sugar content : measured with a electronic refractometer, also connected with a computer

To speed up the identification of sample trays, the bar code sticked on it when the sample was picked will be read with a bar code reader before doing each one of the 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 appropriately the data ; also a reduction of human errors is achieved with this system of automatic identification and storage of measurements.

As it has been explained before, all the processes will be controlled by a computer network, responsible of the following tasks :

- 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.

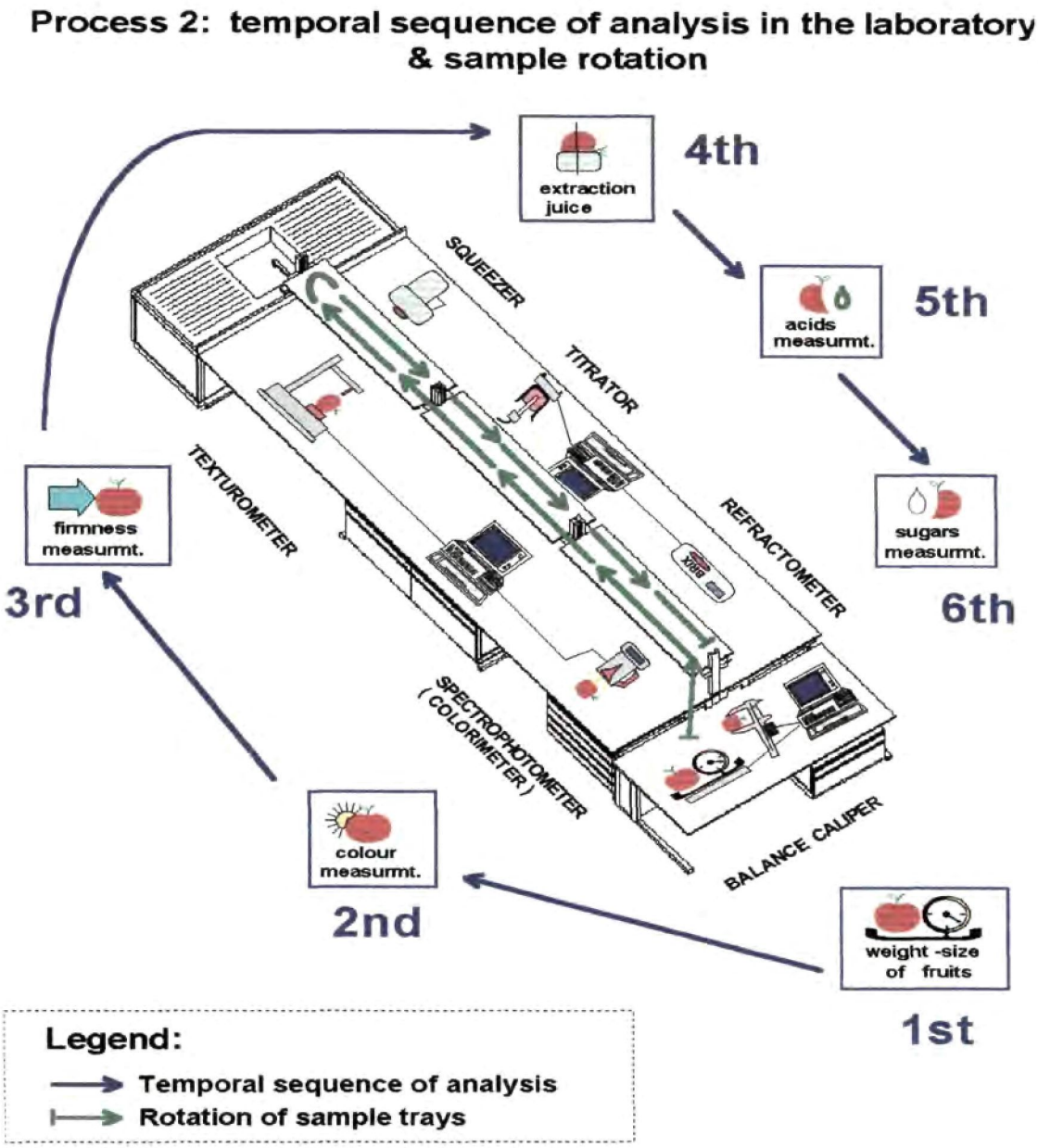

Figure 2. Process 2 of the quality control : in an adjacent laboratory will be performed the measurement of the weight, size, damages, colour, firmness, acids and sugars of a sample extracted from the pallets.

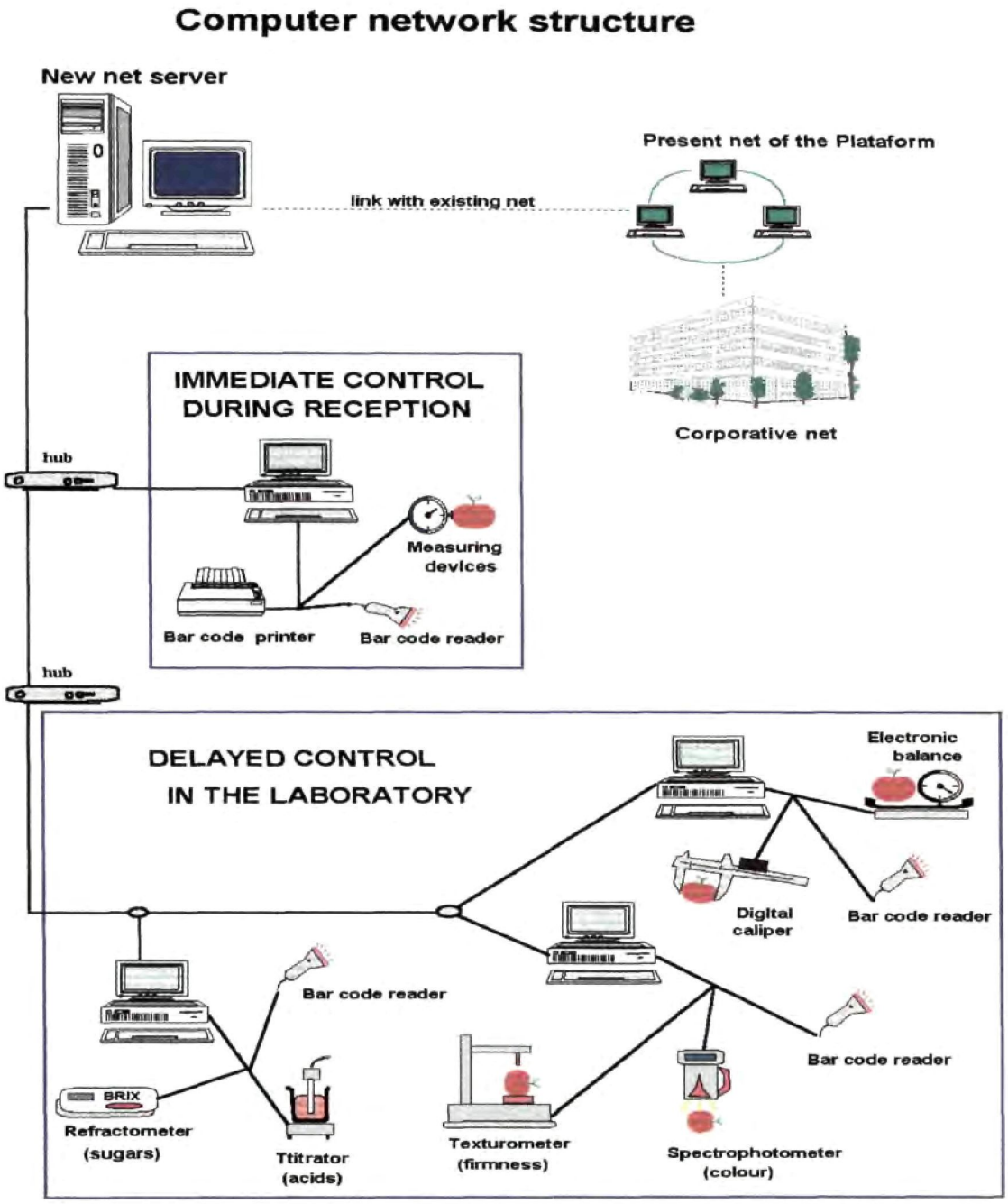

Figure 3. The whole process of quality control must be computer commanded by a network of PCs, responsible of controlling the devices, storing the measurements and maintaining a database.

Another important piece of the quality control system is the software implemented in the computer network. Nowadays, there are enough standard applications developed to perform the different tasks : connect and communicate the computers, maintain a relational database, interface with the equipments. The proposed control process may work perfectly

with a traditional network operating system, a corporative database manager and the small applications that each equipment vendor includes with their measuring devices. Nevertheless, it would be better to program a new software specifically designed to meet the requirements of this control process and optimised to interact with the electronic devices and measuring equipments used in the system. This will solve problems of connectivity, file sharing and direct control of devices.

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 process 1 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 particularised for each fruit, this is, measuring on each species the most important quality parameter instead of all the proposed ones, and starting with the most important fruits in terms of sales. This way, the initial investment will be less, the acquired equipment will be efficiently 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 interest of measurement (Table 3).

Table 3. Recommendations about how to apply the control system gradually, measuring first the most important fruits and parameters.

Type of fruit	*Parameter to measure first*	*Second parameter*	*Third parameter*
Apple	Firmness / texture	Damages	Taste (sugar & acid)
Pear	Firmness	Taste	Damages
Peach	Firmness	Taste	Damages
Apricot	Firmness	Sugar	Colour
Tomato	Colour	Firmness	Taste
Melon	Sugar	Colour	-
Citrus fruits	Mould rots	Spots / damages	Taste

CONCLUSIONS AND DISCUSSION

In this work, an effort to apply the scientific advances of fruit quality detection to the marketing channel has been done. The actual quality control that is being carried out in the fruit trading centres is insufficient and subjective, and the proposed control system combines the use of measurement devices, statistical procedures and computer aid to obtain a rigorous control of the fruit handled daily in a hypermarket.

The advantages of installing such a quality control system are obvious in the light of quality control standard systems :

1. Traceability : if a shipment is rejected or there are complaint, one is able to trace the origin of the problem, and to take measures to avoid it in the future
2. Market (sales) programming and monitoring : with the knowledge of the quality levels of each commodity and their evolution, marketing decisions can be taken accurately as well as price policies.
3. Progressive accumulation of a database to aid the decisions about fruit quality standards, marketing strategies and evaluation of suppliers.

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