Topic 5
"Logistics, food safety and traceabilily"

Oral Presentation

RFID Tracking of Potted Plants from Nursery to Distribution

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Abstract
Secure identification of individual plants is needed in potted flowers industry to guarantee traceability, quality and origin of plants, to protect quality marks and for genetic heritage preservation. Besides, the identification at single plant level allows automated data collection and contributes to oppose the counterfeit phenomenon.
This paper describes how a RFID based traceability system for single potted plant tracking from nursery to distribution in commercial greenhouses during the whole production process of Camellia and Azalea can be implemented. RFID systems operating at three frequencies were evaluated: LF systems were tested in the case of tag insertion in the soil, while HF and UHF systems were adopted using tags embedded in plastic label strongly anchored to the plant roots. Different combinations of mobile and fixed antennas, readers and transponders were evaluated. Reading tests were performed on single or multiple plants, both in dynamic and static conditions. The LF RFID solution resulted suitable in the case of tag insertion in the potting compost. Multiple identification in HF gates is reliable in the case of plants arranged on a trolley passing, at low speed, through a narrow gate. Multiple dynamic pot reading resulted promising with UHF combination of linear and circular polarization antennas.

Keywords: RFID, potted plants, flowers, greenhouse

Introduction

In recent years, globalization and delocalization of production as well as the emerging of new markets have radically changed the potted plants as well as cut flowers routes. Many of the cut flowers that are sold in Europe are produced in developing countries such as Chile, Colombia, Ecuador, India, Kenia, etc. where the expansion of flowers productions is supported both by low production costs and climatic conditions which favour year-round cultivation (Huges, 2000). New technological solutions are needed to manage and safeguard the valuable production of both small and large sized greenhouses. The identification of each single plant makes substitution errors impossible, and is a useful tool for those controlling the materials (Luvisi *et al*., 2010). Interesting applications using radiofrequency identification technology were recently developed for various tree species (Bowman, 2010) and for grapevine. The first experiences on electronic marking of plant samples were attempted to record experimental data about health and growth monitoring by standard plastic label or wristband tags tied to branches (Kumagai and Miller, 2006). RFID technology offers a wide range of solutions for traceability, with different operating frequencies, modulation techniques, communication protocols, and economic value. The identification at single plant level allows automated data collection, contributes to oppose the counterfeit phenomenon, and promotes the originality of the trademark and genetic heritage preservation. A RFID traceability system of the single potted plant was developed for months-long growing process optimization in commercial greenhouses tagging reusable pot trays conveyed on belts (Walking Plant Systems - WPS - Horti System, 2007).

The aim of the present work is to propose solutions for the tracking of potted plants through the whole production and distribution chain. A technical solution for production districts or cooperation systems where growers act together from nursery to distribution reaching the necessary critical mass to promote their products and to afford the market has been envisaged. As usually in growers cooperation systems, the first stages of production, which consist in the propagation of the genetic material, are centralized in large high tech nursery greenhouses where the single item level identification of plant in pots is required. Several, less specialized, growers carry out the growth of the plant till the retailer. Information technology for item tracking along the whole production chain could be useful to connect together small and large stakeholders allowing also the management of quality and logistic strategies in collective network.

Materials and methods

In this research three different operating frequency bands were considered for the identification of potted plants: LF (Low Frequency, 125 and 134.2 kHz), HF (High Frequency, 13.56 MHz), and UHF (Ultra High Frequency, 868÷915 MHz). Tags and antennas were firstly evaluated in laboratory where standard as well as customized solutions were tested.

Afterwards, trials were conducted in a nursery flower greenhouse where Camellia and Azalea are produced from cuttings. In the greenhouse, 280 plants were electronically tagged at first transplant (from alveolated trays to 100 mm diameter flower pot), by means of different type of transponders located in different positions. Transponder readability was periodically checked. Trials were performed to evaluate the feasibility of single and multiple reading in greenhouse both in static and dynamic conditions.

Low frequency

During the first transplant, 120 potted plants were tagged by different types of LF transponder buried in the soil. Three different models of 125 kHz transponder (Sokymat, IN TAG models) have been evaluated. This transponder model is circular shaped, made in specific modified thermoplastic (PA6) suitable for food, waterproof (IP68), shock and vibration resistant, with operating temperature ranging from -20 to +85 °C. The models differ for dimensions (diameter: 30 and 50 mm) and for memory type, as in 50 mm model the memory is read-only, while the 30 mm model is provided with 2 kbit rewritable memory.

Standard ear-tags for cattle electronic identification (Caisley – model Multiflex) operating at 134 kHz and accomplishing ISO standard 11784 and 11785 were also tested. As the device is expensive due to animal tagging requirement, in case of large-scale use in flower industry, the inlay characteristics must be modified to reduce costs. Transponders were all inserted into the soil, both in horizontal and vertical positions (Figure 1). All pots were arranged on movable rolling benches for single static reading test.

Static readings were performed using a mobile PDA equipped with an integrated LF antenna module or connected to a wand antenna. The PDA was a Psion Teklogix – Workabout PRO equipped with 125 kHz LF module and an Edit ID Bluetooth Wand at 134.2 kHz. Dynamic readings were carried out by a static IDtronic – Bluebox model reader, connected to a 200 x 200 mm panel antenna positioned beside the conveyor belt feeding the machine which automatically arrange pots on movable rolling benches. In the case of 134 kHz transponder an EditID (800 x 600 mm) panel antenna was placed under the conveyor belt.

The reading area of the 134.2 kHz panel and wand antenna was already determined in our previous work on animal identification (Gay *et al.*, 2007; Tortia *et al.*, 2008; Escobar Fonseca

et al., 2008), while for the 125 kHz panel, reading area for different tag/antenna coupling was assessed by laboratory tests. Parallel and perpendicular tag orientations with respect to the panel of the antenna were considered.

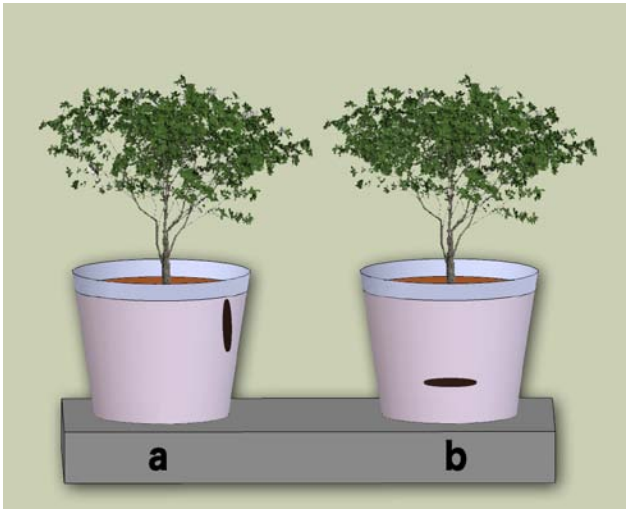

Figure 1. Positions of 125 kHz transponders inside the pot: a) vertical; b) horizontal.

High frequency
80 plants were identified at first transplant by means of custom-made PVC labels embedding HF transponders according to ISO 15693 standard and operating at 13.56 MHz. This label (covered by Italian patent, see Barge *et al*., 2010) consists of two distinct parts: an upper one embedding the transponder (85 x 55 mm) and a holed lower part (80 x 25 mm). The holes allow the roots of the plant, during its growth, to penetrate and surround the label which results strongly linked to the plant and soil. Avoiding the contact of the transponder with the soil, limits the signal attenuation due to water contained in the pot. This solution allows also orienting the transponder in a standard position, which is difficult to accomplish for example with other devices attached to the aerial part of the plant. Static readings were performed using the PDA (Psion Teklogix) changing the RFID integrated module with a 13.56 MHz unit.
Dynamic readings were performed by a static gate composed by an Obid I-Scan HF long range reader (ISO 15693) with 2 W radiating power connected to two single-loop antennas (145 x 85 x 31 mm) in Helmholtz configuration. Gate was 1050 mm wide with antenna center height equal to 1700 mm. Multiple readings were carried out with pots positioned on steel trolleys (1350 x 560, height 1900 mm) commonly used in greenhouse for items handling and shipping. The width of the gate allowed the passage of the trolley carrying the plants. Trolley was manually pulled trough the gate at constant speed ranging from 0.2 to 0.5 m/s (Figure 2). 48 pots were placed on two shelves (740 and 1180 mm respective height) of the trolley with RFID label all oriented in parallel configuration with respect to the reader antenna. In another trial, the same pots were casually set regardless plastic label orientation in order to simulate real production conditions.

Ultra high frequency
A label embedding an UHF transponder was developed as well, composed by the same holed lower part but containing in the upper part an EPCglobal Gen 2, ISO 18000-6 transponder

(Figure 4). As this transponder type is smaller than HF tags, it was possible to obtain an aerial part of only 85 x 35 mm, which is more likely to be used in flower production contexts.
As in the HF experimental set-up, 80 plants were identified. Workabout PRO PDA equipped with UHF module (400 mW radiating power) was used for mobile readings. Both linear Calearo Compact Directional Antenna (170 x 155 x 75 mm) and circular polarization antenna Caen WANTENNAX005 (245 x 235 x 40 mm), were used. In order to evaluate static reading area of UHF antennas, a specific laboratory trial was developed. 128 potted flower were set into a 16 x 8 rectangular grid (3200 x 1600 mm), identified by UHF labels, all parallel oriented with respect to the antenna, which was placed at the centre of the longer side. Reading number of every single transponder in a set time period was used to assess the reading area. Another trial was carried out with 40 plants arranged into a 5 x 8 square grid in order to evaluate reading efficiency simulating reading of plants set on benches of the greenhouse by two UHF linear antennas positioned in different configurations at a constant height of 650 mm with respect to the plane where pots were laying. Then, multiple dynamic readings were conducted in greenhouse on pots placed both on movable rolling bench (5800 x 1630 mm) and on trolleys. To enhance the pots number, some pots were filled by soil and identified with the label. Dynamic multiple reading tests were performed with Camellia and Azalea potted plants set on rolling bench moving at 0.07 m/s forward speed with 2 linear polarization antenna in staggered configuration. The efficiency improvement occurring adding a circular polarization antenna was assessed. A specific 1950 x 2200 mm wide gate with 4 linear and circular polarization antenna was built for multiple dynamic reading of 129 potted flowers set on five shelves of a trolley, which was spinning on a platform commonly used for trolleys wrapping with plastic film before shipping (Figure 3).

Figure 2. Multiple dynamic reading of 48 potted plants electronically identified by HF plastic label transponders.

Figure 3. Dynamic multiple reading of 129 potted plant identified by means of plastic label UHF transponder during wrapping process before shipping.

Results

At the end of the trial all transponders resulted in good operating conditions after 8 months spent in greenhouse. Tag presence in the soil didn't affect normal plant development along all greenhouse production cycle. The growth of the aerial part of the identified plants has not been affected by the presence of the transponder with respect of control plants (without tag). Tags buried in the soil resulted completely enclosed in the plant roots and they were even difficult to find without the aid of RF detection.

The lower part of HF and UHF electronic labels were firmly fastened to the soil. At the growth stage reached at the end of the trial, both for Camellia and Azalea plants, the whole potted plant could be even raised from the bench grasping the label without risk of label detachment (Figure 5).

Figure 4. Insertion into the soil of custom-made PVC label embedding an UHF transponder at first transplant.

Figure 5. After 8 months of growing the whole potted plant could be even raised grasping the label without risk of detachment.

Low frequency

The 125 kHz panel antenna reading area resulted similar in shape to the 134.2 kHz one, but, due to the smaller dimensions and the lower radiated power, maximum reading distance in the air, between tag and panel antenna ranged from 180 to 250 mm respectively for perpendicular and parallel orientation. When the transponder was surrounded by the soil, maximum reading distance decreased on average by 20%. In greenhouse dynamic reading tests of flowerpots spaced out at 650 mm and moving on the conveyor belt at 0.2 m/s constant speed, only the configuration beside the belt was effective on vertically inserted transponders (Fig. 1- a) Transponder models INTAG 300 and INTAG 500 resulted always readable in any orientation with respect to the antenna. However, due to the low reading area the antenna should be placed very close to the pots.

On the contrary, the 134 kHz Edit-ID panel antenna placed under the conveyor belt allowed 100% dynamic single reading of tags inserted both in horizontal and vertical position when plants were moving on the conveyor belt spaced at 650, 400 and 300 mm mean distance among each other. At distances among pots lower than 250 mm, the 134.2 kHz panel antenna

reading performance decreased. As during the transplant in normal operating conditions, the pots are usually placed on the conveyor very close to each other this configuration results not suitable for greenhouse application. In laboratory trials conducted simulating the conveyor by a trolley, it was observed that the collision among tag contemporarily present in the reading area affected the reading performance. However, reducing reading area by means of two metal screens, leaving only a 2 cm of the panel uncovered, 100% reading performance on pots close to each other was obtained only in the case of tag placed parallel to the antenna (Fig 1b). LF tags reading by means of mobile device (PDA) resulted very difficult and sometimes impossible, while 134.2 kHz wand antenna allowed maximum reading distance ranging from 200 to 300 mm depending on mutual tag-wand orientation. Reading distance resulted not to be affected by water presence in soil. By means of the wand, an operator can identify each potted plant arranged on the greenhouse bench.

High frequency
Maximum reading distance of a 35 mm diameter transponder loop placed in parallel position in front and at the centre of a single Obid long-range antenna resulted 700 mm, while the shape of the reading area obtained in laboratory is similar to LF panel antennas. Thus, the 1050 mm wide gate employed, allowed 350 mm reading area overlapping. The results of both dynamic trials whit HF gate are reported in Table 1.

Table 1. Dynamic multiple reading of 48 potted plants electronically identified by means of HF plastic label. Plants were set on a two shelves pot plant trolley.

Tag/antenna orientation	*Trolley forward speed (m/s)*	*Reading efficiency (tag read/tag present)*
parallel	0.20	100%
	0.35	100%
	0.50	85%
random	0.20	83 %

Dynamic multiple reading trial at trolley linear speed up to 0.35 m/s of plastic electronic labels arranged all in parallel orientation gave good results (Tab. 1) while, when the trolley speed reached 0.5 m/s, only 85% of tags were correctly detected. In case of randomly orientated labels, only 83% tag reading efficiency was obtained at the lower speed tested (0.2 m/s linear speed).

Ultra high frequency
Static reading test showed that a single linear polarization UHF antenna can cover an hypothetic area of the bench of 1000 x 1400 mm, detecting correctly all the tags in parallel configuration. Only by two linear polarization antennas set in parallel and staggered configuration at a distance of 800 mm, all the considered area was covered.
Dynamic multiple reading tests of a total of 160 Camellia and Azalea plants set on rolling bench with 2 linear polarization antenna in staggered configuration showed a maximum reading efficiency equal to 96% (Table 2). Antenna orientation was parallel with respect to bench forward direction. No reading efficiency improvement occurred with additional circular polarization antenna installed upon the bench in perpendicular orientation with respect to bench forward direction. A 1950 x 2200 mm wide gate composed by 4 linear and circular polarization antennas was built for multiple dynamic reading of potted flower set on trolley.

This latter was spinning on a platform commonly used for trolleys wrapping with plastic film before shipping (Figure 3).

Figure 6. Psion Workabout Pro PDA reading 40 potted Camellia and Azalea electronically identified by means of plastic label UHF transponder.

In a first trial, where all circular polarization antennas were mounted on the gate, the reading cycle began when the trolley was already placed on the platform and lasted 47" which was the normal elapsed time for the wrapping process. After 8 repetitions, a mean number of 127.7 on 129 tags were read (Table 3).

Table 2. Dynamic multiple reading on movable rolling bench of 80 potted plant electronically identified by means of UHF plastic label by means of different configuration of linear polarization antennas.

Antennas configuration	*Gate dimension (m)*		*Bench speed (m/s)*	*Mean reading efficiency (tags read/tags present)*
	width	*height*		
2 parallel-frontal	1.63	1.2	0.07	86 %
2 parallel-staggered			0.07	96 %

Table 3. Dynamic multiple reading of potted plants identified by means of UHF plastic label by a gate composed by different combination of linear and circular polarization antennas.

Gate configuration	*Reading cycle time (s)*	*Mean reading efficiency (tags read/tags present)*
4 circular	47	99%
4 circular	57	100%
2 linear + 2 circular	57	100%

In a second trial the reading time was extended of 10", which was the time employed for the loading on the spinning platform by an operator. In this case, after 8 repetitions, 100% reading efficiency was obtained. The last test was performed alternating linear and circular polarization antennas in the gate. Reading cycle lasted 57" and started 10" before trolley load on spinning platform. Also in this case 100% mean reading efficiency was attained. The

Workabout PRO PDA was used in greenhouse to periodically check the operational status of UHF label transponders (Figure 6). This device could read simultaneously 40 pots identified by labels staying at the end of the bench.

Conclusions

LF technology at 125 kHz is a viable solution only if the tag must be buried in the soil, however the short reading distances are limiting. LF identification is possible on benches only using a wand, which is a very time-consuming solution. LF dynamic identification on conveyor belts is not optimal, as major changes with respect to the normal working parameters must be adopted.
HF systems resulted suitable for the single reading by the PDA, but in multiple dynamic reading of RFID plastic label tags, position highly influences reading performance.
UHF systems can be applied in greenhouse both for single static and multiple dynamic identification of plants tagged by means of the label adopted in the project.
Plant traceability management by UHF systems can be performed at item level and identification can be performed by an operator with a PDA both on single or a group of plants or by gates both on bench and on trolley. The particular shape of the HF and UHF labels allow to fasten strongly the tag to the plant roots not compromising the normal growth.

Acknowledgements

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References

Barge P., Gay P., Tortia C. 2010. Etichetta elettronica con sistema di ancoraggio radicale per l'identificazione a radiofrequenza delle piante in vaso, Italian patent n. TO2010A000472.

Bowman K. D. 2005. Identification of woody plants with implemented microchips. HortTechnology, 15 (2), 352-354.

Bowman K. D. 2010. Longevity of radiofrequency identification device microchips in Citrus Trees. HortScience, 45 (3), 451- 452.

Escobar Fonseca J., Gay P., Piccarolo P., Ricauda Aimonino D., Tortia C. 2008. Information technology for meat supply chain traceability. Int. Conference "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems", Ragusa, 15-17 September 2008.

Gay P., Giuffrida M.P., Piccarolo P., Ricauda Aimonino D., Tortia C. 2007. Livestock and Farm Management Improvement using RFID Technologies. Proceedings of 32th CIOSTA Congress "Advances in labour and machinery management for a profitable agriculture and forestry", Nitra, 17-19 September 2007.

Hughes A. 2000. Retailers, knowledges and changing commodity networks: the case of the cut flower trade. Geoforum, 31 (2), 175-190.

Kumagai M. H., Miller P. 2006. Development of electronic barcodes for use in plant pathology and functional genomics. Plant Molecular Biology, 61, 515-523.

Luvisi A., Triolo E., Rinaldelli E., Bandinelli R., Pagano M., Gini B. 2010. Radiofrequency applications in grapevine: from vineyard to web. Computer and Electronic in Agricolture, 70, 256-259.

Tortia C., Gay P., Piccarolo P., Ricauda Aimonino D. 2008. Livestock identification and farm management by RFID systems. AgEng - International Conference on Agricultural Engineering, Hersonissos, 23-25 June 2008.

WPS Horti System. www.wpshortisystems.nl

Innovative Concepts for Traceability Software of Orchard Production

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Abstract
The requirements of traceability applications are function of the level of detail requested by traceability protocols (mandatory requirements, GlobalGap, Nature Choice's) and of the needs to communicate the data along the fruit supply-chain, in electronic format. Some applications are available on-line. Three of them have been subjected to trials. The following defect were common among them: the application is built to satisfy all users, so it is quite complex for small farmers or for mandatory level of information tracing; the chemical database is not updated when needed, so farmers cannot load into the application the state-of-the-art, newly formulation even if allowed on the specific orchard; the user interface is sometime difficult to use for farmers, that are often reluctant to the use of software in general; too many controls during the insertion do not allow to insert partial data and delay the information recording. Specifically, some operation often carried out by the farmer (e.g. spraying of fungicides, insecticides) are difficult to insert because have to be carried on a single parcel for the software. The defects often prevent farmers to do the traceability task while carrying out the real activities. Instead, they prefer to do it at the end of the campaign. In this way the information is not available when the product is harvested. These considerations lead the authors to develop during two year project a stand-alone software for traceability, with focus on spraying operations. Among the peculiar features of the software the spraying on groups of parcels that allows to greatly reduce the data recording, the post-data control that allows partial data to be inserted into the application.
In this way, the farmer can easily use the software and control the storage of chemical, load the product into the system even after chemical application. The paper present the main features of the application being developed and an example of application.

Keywords: traceability, software, orchard, spraying

Introduction

From the comparison of different management solutions on the market for traceability, we assessed those most in use in the Piedmont Region. The applications have proved very similar to each other and the main differences are referred to: how to define the batch production/lot size, the database of pesticides/fungicides, the refresh rate of the database and the presence of custom specifications that gradually have been requested by customers.

Almost all computer programs for the traceability of the market provide centralized management of several databases that are normally given for hire by paying an annual fee. The main limitation to their diffusion is given by the unwillingness of farmers to invest time in recording the data in electronic format. Very interesting is the opinion of users who wonder how the first condition is the operation usefulness, in terms of ease of insertion and retrieval of data.

The update of data on allowed pesticide use is often slow and dot timely to meet the needs of farmers and this greatly limits the spread of certain applications. The level of computerization in agriculture stands as an important aspect in the diffusion of application traceability, particularly in proper use of modern management systems in the traceability chain of fruit. The difficulty of access to fast Internet connections or the need for special hardware are today

still limiting to the dissemination of management systems and computerized tracking and tracing fully managed via web.
The computer approach is therefore more restrained in terms of distribution of the application among the farmers; To fill this gap, DEIAFA has created a stand-alone Access ®-based registration application for fast data log that comply also with certain requirements of the GLOBALGAP Protocol. The project's objective is to develop an integrated application for managing the activities of the orchard production, with the inclusion of information relating to compliance law (e.g. logbook), but that is also used as an aid in drawing up the plan of fertilization and water balance of fruit orchards and irrigation management.

Methods
The database was created in Microsoft Access ®. The database is designed to handle a single user at a time and then a single farm, as it was designed for use by individual companies. Since managing a single company, the database does not require password authentication.

The main menu includes the following groups of procedures:

Minimum Lot: small lots are inserted, i.e. the single field portion on which is cultivated the same with the same year of planting. This means that in a single field we can register more than one minimum lot. For treatments, fertilization and harvesting operations, the small lots are grouped into homogeneous entities referred below as groups. The group includes small lots homogeneous by species or varieties, or parcels located in a certain defined area of the farm.

Figure 1. Form for the insertion of the single parcel

Create / delete group: you can group minimum lots in homogeneous classes related to species, varieties and location specification, in order to simplify the implementation of treatments and fertilization. The procedures developed allow you to create automatically with the use of set operations AND / OR / NOT any grouping of small lots and encode it for later use while performing spraying, irrigation or fertilization. It is also allowed the construction of a group with the manual insertion of minimum lots. The application refers to these groups while registering information on spraying or fertilization.

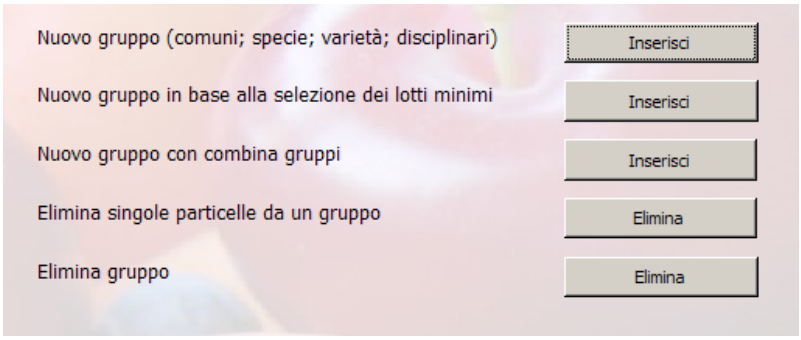

Figure 2. Operations that can be carried on the group management menu

Treatment: you can load the treatments, indicating the products (pesticide/fungicide) used, the total amount of active ingredient used and the group or groups on which the treatment was performed. The registration of a treatment on different groups is done in one step.

Harvest/picking: Defines when the intervention was made, the product types (apples. Peaches, nectarines), the lots / groups on which the collection was made

Fertilizer: this procedure allowed to register the fertilizer used like for the spraying.

Storage of pesticides/fertilizers: the user can register movements such as loading, unloading and the initial stock. Fertilization and spraying and inserted automatically as unloading of the products, when the user insert the treatment or the fertilization.

Views: this procedure allows to access to reports where treatments are shown on each plot, sorted by date, by particles and small lots that constitute a single group. Also the stock movements and products with negative stock are presented.

Peculiarities related to group management
The management of homogeneous groups of particles, called minimum lots, it is essential to speed up the records of treatments and fertilization, which can be executed on the group, not on the individual lot. The group is a set of minimum lots, homogeneous on some characteristics, created on purpose by the user. What differentiates the tool developed is the ease in the composition of groups with operators as intersection, union and negation of sets.

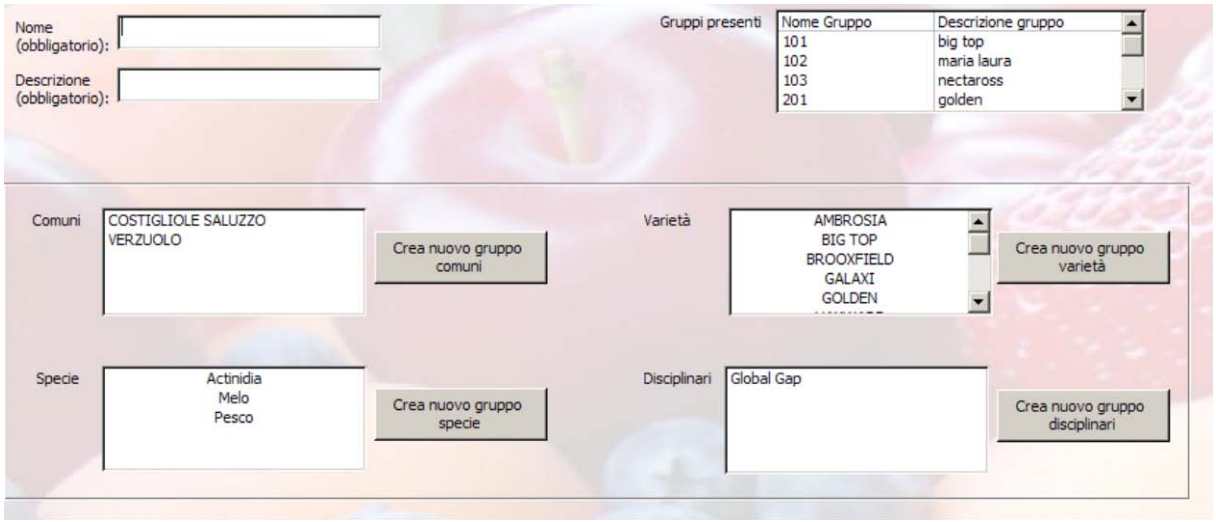

Figure 3. Operations that can be carried on the new group form

With the new option group by selecting the minimum lots you can manually create a group by choosing which small lots are part of it. This is the classic option, which many procedures on the market have, and allows to form groups by selecting among all the particles of the farm.
With the "groups combination" the user can combine groups created with previous options. In this form are requested the name and a brief description of the group, and two windows, displays all the groups already present. You must select a group on the right screen, a group on the left screen, and highlight the option you want to use for combining the two groups:

- an intersection of sets, which will result as all the particles present in the first and second group. Just an example, if you choose apples left the group and right group golden apples, the result will still be the set of particles containing the group golden apples, as a subset of the apples;
- the of union of sets, which will have all the resulting particles is the first group, and in the second group, without duplicates. The union operation applied to the previous case will generate a group containing all the apples, as the group golden apples is already completely contained in the group apples;
- a subtraction operation, which will generate results in all particles present in the first group that are not present in the second. Applied to the previous case, the new group will include all particles with apples except those that are planted with golden apples.

The Figure 4 present the form visualized to combine the groups.

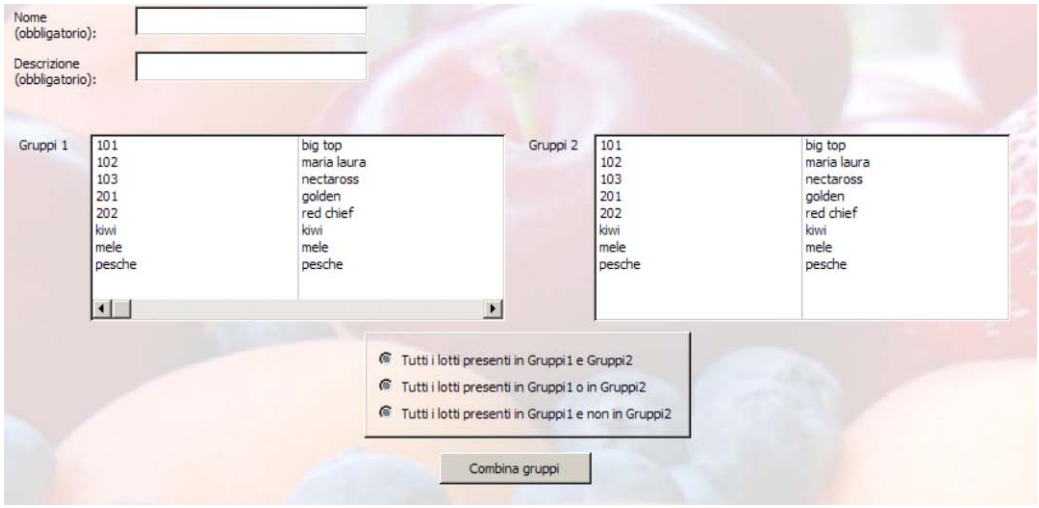

Figure 4. Operations that can be carried on the combine group form.

The combination of the groups mentioned above with the operations of intersection, union, and subtraction to generate all the groups needed to register the spraying and fertilization in one step. It is convenient to generate all groups before starting to enter treatment, and is convenient to generate homogeneous groups by type of treatment in order to expedite the placing of the treatments. Groups can represent the union of simple groups, or groups of second and third level without limit to the number of levels.
For example if a user creates a group for each variety of nectarines, he can then combines them into a single group that contains nectarines using these options, creating a single group of nectarines used for treatments. Instead, when he register the harvest, he will use the single variety of nectarine group.

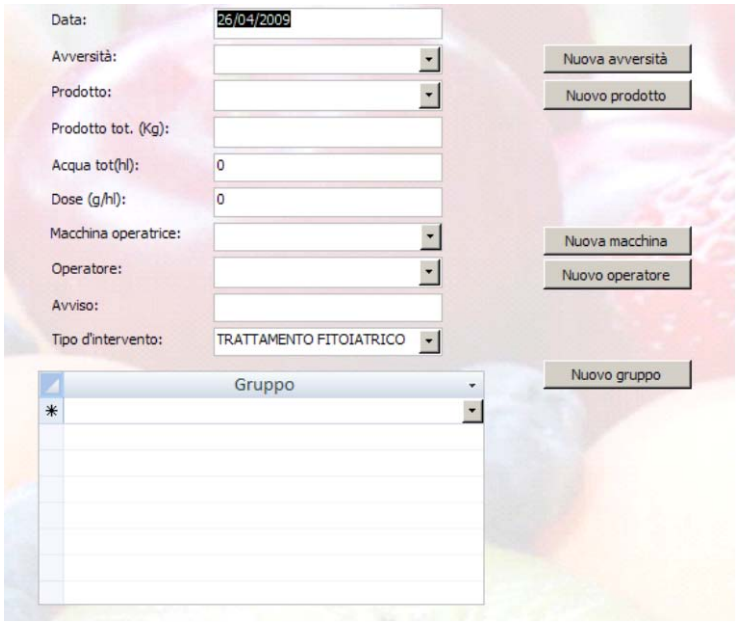

Figure 5. Insertion of new spraying intervention form

Defined these data, the user could register the treatment or the fertilization. When the user enters the groups on which treatment was performed, he can push the new button group, if a group missing and define it immediately. In this case it will appear the screen for defining groups.
The user can freely select multiple groups for each treatment. The total doses of product and water will be distributed evenly among all small lots that are part of the groups selected for treatment, in a completely automatic way.
The application allows the inclusion of a treatment even if the user has not yet uploaded to the active inventory the product, to ensure the partial information storage, which can be completed later.
The application is provided with control application to verify proper data input and control inventory in stock to avoid drawing erroneous records.
With the report referred to the Figure 6, the user gets the view of inventory of products with negative stock, which require a load of product at a date less than that in which they were used.

Controllo prodotti e giacenze

Ragione sociale: AZIENDA BRUNETTI PAOLO **Indirizzo:** Via Ronconi 31 **Comune:** SAN MAURO TORINESE

Nome commerciale	Principio attivo	Numero di registrazione	Data	Disponibilità	Intervento	Check data control
OLEOTER	Olio Minerale	3102	02/03/2007	-260,00	TRATTAMENTO FITOIATRICO	Effettuare il carico entro la data 02/03/2007
TRISCABOL DG	Ziram	3486	02/03/2007	-12,00	TRATTAMENTO FITOIATRICO	Effettuare il carico entro la data 02/03/2007
OLEOTER	Olio Minerale	3102	02/03/2007	-360,00	TRATTAMENTO FITOIATRICO	Effettuare il carico entro la data 02/03/2007
MAVRIK 20 EW	Fluvalinate	9800	08/03/2007	-1,50	TRATTAMENTO FITOIATRICO	Effettuare il carico entro la data 08/03/2007
NITRATO AMMONICC	26% N		04/08/2010	-850,00	CONCIMAZIONE MINERALE	Effettuare il carico entro la data 04/08/2010

Figure 6. Report to control product with negative storage

Conclusions

The application requirements are tracking the level of detail required by specifications and protocols for traceability, and the need to communicate such data to downstream production in electronic format.
Often the requests and customizations for individual users are not implemented by software developers, so the addition of amendments to existing applications is often with a certain slowness. Even the registration of new pesticides on the database required too much time compared to the needs of the farmers.
When the famer follow the minimum, mandatory traceability protocols his goal is to minimize data entry so the use of simpler, fast applications may be ideal.
To fill this gap DEIAFA created a stand-alone based Access ® for fast data recording logbook and to comply with certain requirements of the Protocol GLOBALGAP. The application is currently used on eight pilot farmers. This application has all the advantages of a purpose-built application, with simple graphical interface, with no redundant data request.
The feedback from farmers will help to improve the application in the future.
At present the application is single user and runs a company at a time. This simplifies a lot the data management by the farmer or technician responsible for entering data for traceability. This application, however, does not allow grouped analysis of different farmers, as it could be done in the future with applications that use a single central database (Agritracer, Image Line and the CCSC-Bluarancio Coldiretti).
The purpose of traceability for many farmers has the only function of ensuring the aspects of traceability and food safety thereof. It would be interesting to go on to examine the use of traceability data or to assess the costs of production from one side, or to enhance the product in the eyes of the consumer on the other side.
This second objective, however, requires a tracking system integrated along the supply chain so that information entered along the supply chain are available to the consumer. This could be interesting to implement a new research with the integration of traceability from producer to consumer.

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Colour Camera Characterization of a Computer Vision System Using LS-SVM Regression

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Abstract
The aim of this work is to evaluate the potential of least squares support vector machine (LS-SVM) regression to solve the colour camera characterization problem in computer vision systems (CVS). A laboratory CVS, based on colour digital camera (CDC), was implemented and three LS-SVM models were trained and validated, one for each output variables (L*, a*, and b*) required by this problem, using the RGB signals generated by the CDC as input variables to these models. The colour target-based approach was used to camera characterization and a standard reference target of 242 colour samples was acquired using the CVS and a spectrophotometer. This data set was split in two sets of equal sizes, for training and validating the LS-SVM models. An effective two stage grid search process on the parameters space was performed in MATLAB to tune the regularization parameters γ and the kernel parameters σ^2 of the three LS-SVM models. The LS-SVM models developed in this research allowed to obtain high correlations between L*a*b* data acquired using the spectrophotometer and the corresponding data obtained by transformation of the RGB data acquired by the CVS. In particular, for the validation set, R^2 values equal to 0.999 for all the three chromatic parameters were obtained. The RMSE values were 0.32, 0.32, and 0.27 for L*, a*, and b* respectively, and the average of colour differences ΔE_{ab} was 0.82±0.54 units. Thus, LS-SVM regression seems to be an useful tool to solve the camera characterization problem in the CVS.

Keywords: food, CIELAB colour space, colour measurements

Introduction

In recent years, computer vision systems (CVS) based on colour digital cameras (CDC) have been shown to be a good tool to quantify easily and quickly the colour of any food, using equipment that is readily available at reasonable cost (Mendoza et al., 2006). However, there are some issues that are important to consider for colour measurements, especially where colorimetric precision is important. Specifically, the RGB signals generated by a colour digital camera are device-dependent, and these colour signals are not colorimetric. Therefore, in order to objectively measure colour and detect colour features from food products with accuracy, a colorimetric transformation that defines a mapping between the device-dependent RGB signals and a device-independent colour space, such as the L*a*b* (or CIELAB) colour space, is an essential step in the implementation of any computer vision system (Valous et al., 2009). The transform derivation process is referred as device or camera characterization.

Recently, León et al. (2006) used a multilayer feed-forward neural network (MFNN) with back-propagation to predicts the L*a*b* values from the RGB values generated by a CDC with good results. However, MFNN suffer critical drawbacks including learning stopping at local minima, over-fitting, and selection type depending excessively on experience (Wang et al., 2009).

Support vector machines (SVM), a new learning algorithm based on the statistical learning theory, can model linear and nonlinear mappings without these disadvantages (Vapnik, 2000). Unlike the classical neural networks approach the SVM formulation of the learning problem leads to quadratic programming (QP) with linear constraint. However, the size of matrix involved in the QP problem is directly proportional to the number of training points. Hence, to reduce the complexity of optimization processes, a modified version, called least squares support vector machines (LS-SVM), have proposed (Sukens, Vandewalle, 1999). LS-SVM encompass similar advantage as SVM, but its additional advantage is that it requires solving a set of only linear equations (linear programming) that is much easier and computational more simple.

In this study, after the implementation of a laboratory CVS based on a CDC, the objective is to evaluate the potential of LS-SVM regression to solve the camera characterization problem. For this purpose, three LS-SVM models were trained and validated, one for each output variables (L*, a*, and b*), using the RGB signals generated by the CDC as input variables to these models.

Materials and method

Computer vision system

The implemented CVS has three main components: an illumination source, a colour digital camera (CDC) and an image processing software. The light source consisted of four fluorescent 15 W lamps (Neon OSRAM TLD65-15W, Germany) with a colour temperature of 6500 K, arranged in a square 0.68 m above the sample. To ensure uniform illumination, the four lamps were connected to electronic ballasts and covered with plastic light diffusers.

The colour digital camera was a Canon EOS 400D (Canon, USA) located vertically over the matte black background at a distance of 0.45 m. The camera was connected to the USB port of a PC (Asus, Taiwan) with a Remote Capture Software (version 2.7.2, Canon, USA) to visualize and receive the digitized images directly from the computer.

As standard setting conditions, the viewing/illuminating geometry was about 0/45. Moreover, the sample illuminators and the camera were placed inside a wooden box with black internal surfaces to exclude external light and reflection. A standard white card (X-rite ColourChecher® White balance Card, USA) was used to set manually the white balance of the CDC. Spatial correction was performed in order to minimise the effect of any lack of spatial uniformity in the intensity of the illumination or of the sensitivity of the CDC. The spatial correction method was based on work by Westland et al. (2004). Manual exposure mode and both lens aperture (f = 6.3) and exposure time (1/4) where fixed during the period of image acquisition. In this experimentation, all the image were acquired with resolution of 3888×2592 pixels (corresponding to a field of view of 32.4×21.6 cm^2), and stored in TIFF format. The image processing software was performed using the MATLAB v7.0 (The MathWorks, USA) image processing toolbox.

Reference target

A practical method to camera characterization, referred as to colour target-based approach, was used. The basic idea of colour target-based characterization is to use a reference target that contains a certain number of colour samples of known CIE (Commission Internationale de l'Eclairage) values which are contrasted with the output average signals captured in standard illumination conditions by an imaging sensor (Hong et al., 2001). In this study, the reference target was the Kodak Q-60R2 reflection chart on Kodak Professional

paper (Eastman Kodak Company, USA). This chart is manufactured in accordance with ANSI IT8.7/2- 1993 and ISO 12641 standards and it provides 264 colour samples, including a 22 step neutral scale, which cover a large gamut in the CIELAB colour space.

Colour measurements

For colour measurements, the reference target, located in the centre of the camera field view, was imaged to obtain for each colour samples the camera RGB values in the theoretical range 0-255. The camera RGB values for each colour sample were measured using a MATLAB program which computes the average RGB values of 80% of the pixels in the samples, excluding the boundary pixels. Then, the L*a*b* values of each colour samples (D65 illuminant and 2° observer) were measured using a spectrophotometer (KONICA MINOLTA SENSING Inc., CM-2600d, Japan). This instrument measure spectral reflectance from 380-700 nm in 20 nm intervals from a circular area of 3 mm diameter using a silicon photodiode and a diffraction grating device. The specular component included (SCI) mode was set and the white reference was the white calibration plate of the spectrophotometer (L*=99.30, a*=-0.09, b*=-0.17). In total, a data set of 264 RGB measurements and their corresponding L*a*b* measurements were obtained from the CVS and the spectrophotometer respectively. This data set was split in two sets of equal sizes, for training and validating the LS-SVM models.

LS-SVM models

The LS-SVM regression can be expressed as (Liu et al., 2009):

$$y(x) = \sum_{k=1}^{N} \alpha_k K(x, x_k) + b$$

where $K(x, x_k)$ is the kernel function, α_k is the Lagrange multiplier called support value, b is the bias term. Currently, there is no systematic methodology for selection of kernel function. However, compared with other feasible kernel functions, radial basis function (RBF) as a non linear function is a more compacted supported function kernel and able to reduce the computational complexity of the training procedure and give good performance under general smoothness assumptions (Liu et al., 2009). Thus, RBF kernel was adopted as the kernel function of the LS-SVM models in this study. It can be expressed as follows:

$$K(x, x_k) = \exp\left(-\|x - x_k\|^2\right) / \left(2\sigma^2\right)$$

whereas σ^2, the squared variance of the Gaussian function, is the kernel parameter. To achieve high level of performance with LS-SVM models, two parameters have to be tuned, the regularization parameter γ and the kernel parameter σ^2. Choosing an appropriate regularization parameter and the kernel parameter is an important task and mostly depend on the realized application type. The regularization parameter γ determines the trade-off between structural risk minimization principle (SRM) and empirical risk minimization (ERM), and is important to improve the generalization performance of LS-SWM model. The kernel parameter σ^2 controls the value of function regression error, and influences directly the number of initial eigenvalues/eigevectors. Small values of σ^2 yield a large number of regressors and eventually it can lead to over-fitting. On the contrary, a large value of σ^2 can

lead to a reduced number of regressors, making the model simpler, but eventually not so accurate.

Therefore, an efficient search strategy is needed to tune γ and σ^2. In this study, we employ a two stage grid search process on the parameters space. For this purpose, a coarse grid search process is firstly employed to narrow down the search region of the parameters space. In coarse search process, the incremental steps of grid are considerable big to obtain an enough search space. For each grid points, the mean square error (MSE) from L-fold cross validation is determined and minimum MSE interval is detected. In L-fold cross-validation, the trained data is randomly split into L roughly equal subsets. An LS-SVM model is trained using (L-1) of those subsets and validated on the subset left out. This procedure is repeated L times with each of the L subsets used as the validation subset in turn. Averaging the validation errors over the L trials gives a prediction of the generalization error. Then the search is tuned to a finer search in the region where the predicted MSE value from the L-fold cross-validation is the lowest in the coarse search. The minimum MSE value indicates the optimum LS-SVM parameters. All the calculations were performed using MATLAB v7.0 (The MathWorks, USA). The free LS-SVM toolbox (LS-SVM v1.5, Sukens, Leuven, Belgium) was applied with MATLAB to develop the LS-SVM models.

Performance evaluation

The statistics used for estimating the performance of the regression models developed by LS-SVM included determination coefficients for the validation set (R^2) and root mean square error for the validation set (RMSE). Moreover the average and standard deviation of colour differences between the L*a*b* values predicted from the measured RGB values and the L*a*b* values measured with the spectrophotometer for the validation set were computed. The colour differences ΔE_{ab} were computed by the following equation:

$$\Delta E_{ab} = \sqrt{\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2}$$

Results

In this study the kernel parameters were optimised for each output variables with values of γ in the range of 2^6-2^{13} and σ^2 in the range of 2^2-2^6 with adequate increments. These ranges were chosen from previous studies where the magnitude of parameters to be optimised was established. For each combination of γ and σ^2 parameters, the mean square error of 5-fold cross validation was calculated and the optimum parameters were selected when produced smaller MSE.

The optimising process for L*, a*, and b* was shown in Fig.1, 2, and 3 respectively. The grid '.' in the first step is 10×10, and the searching step in the first step is large. The optimum search area is determined by error contour line. The grid '×' in the second step is 10×10, and the searching step in the second step is smaller. The optimal search area is determined based on the first step. The optimal pair of (γ, σ^2) was found at the value of γ = 6098.31 and σ^2= 12.05 for L*, at the value of γ = 15420.61 and σ^2= 7.59 for a*, and at the value of γ = 203377.21 and σ^2= 16.83 for b*.

The high R^2 values, equal to 0.999 for all the three chromatic parameters, with low RMSE values of 0.32, 0.32, and 0.27 for L*, a*, and b* respectively, showed that LS-SVM has strong ability for regression analysis (Fig.4, 5 and 6). Moreover, the low average ΔE_{ab} of 0.82±0.54 units showed that the LS-SVM approach provides consistent and accurate results in camera characterization.

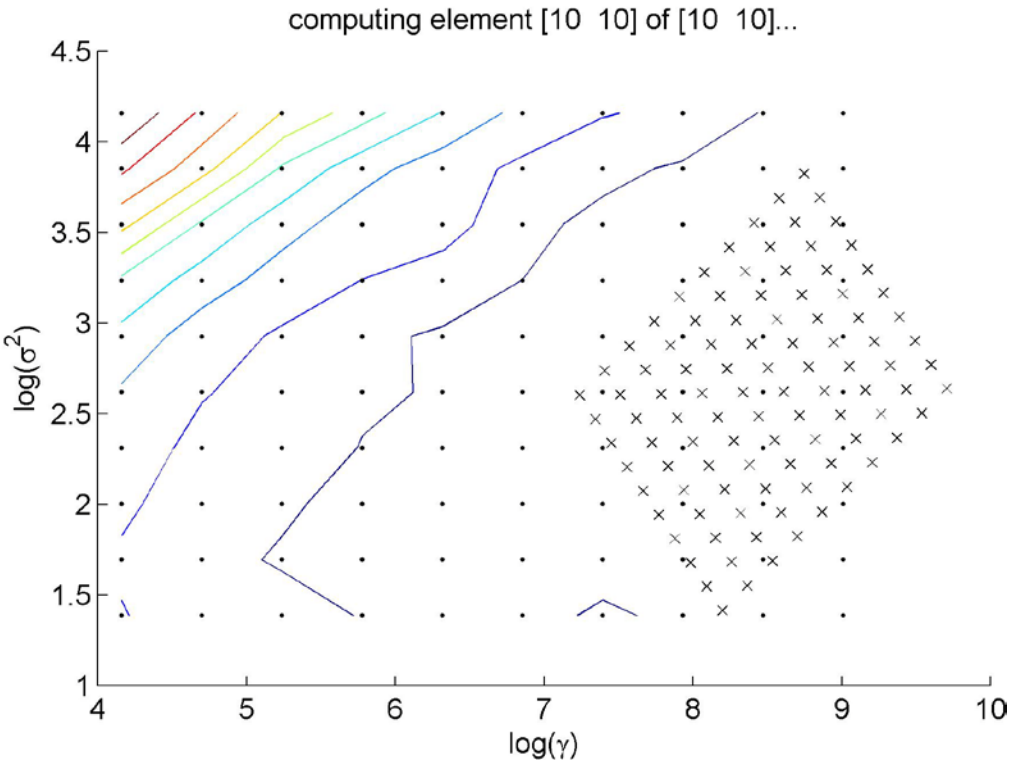

Figure 1. Grid search on γ and σ^2 for the prediction of L* values.

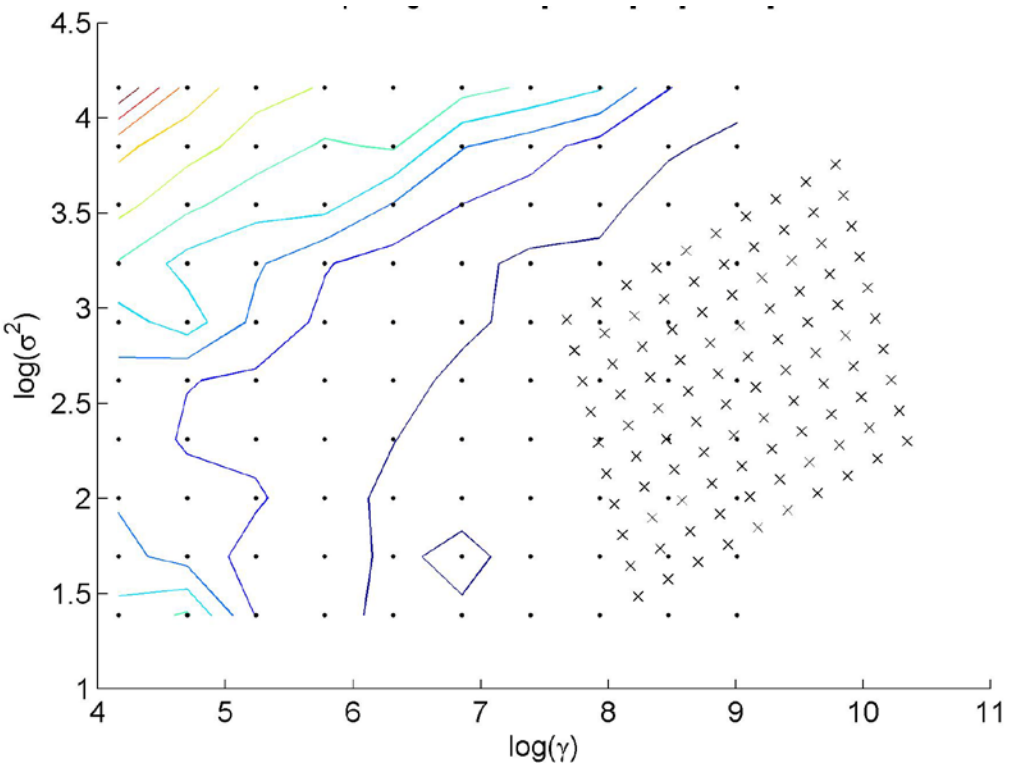

Figure 2. Grid search on γ and σ^2 for the prediction of a*values.

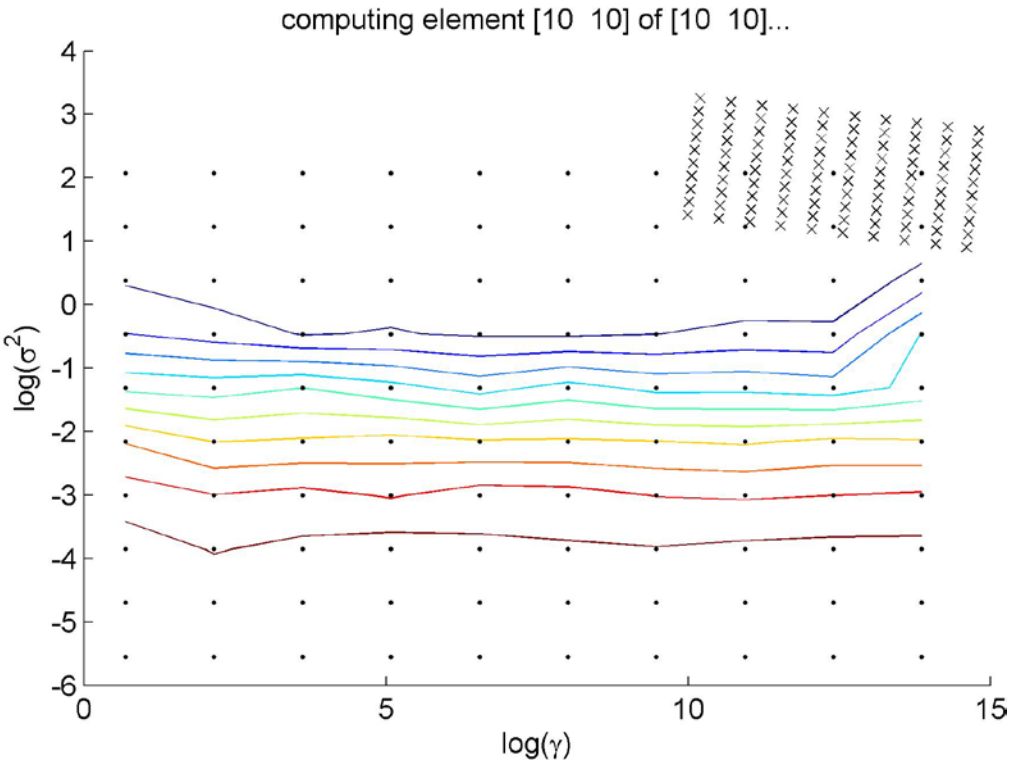

Figure 3. Grid search on γ and σ^2 for the prediction of b* values.

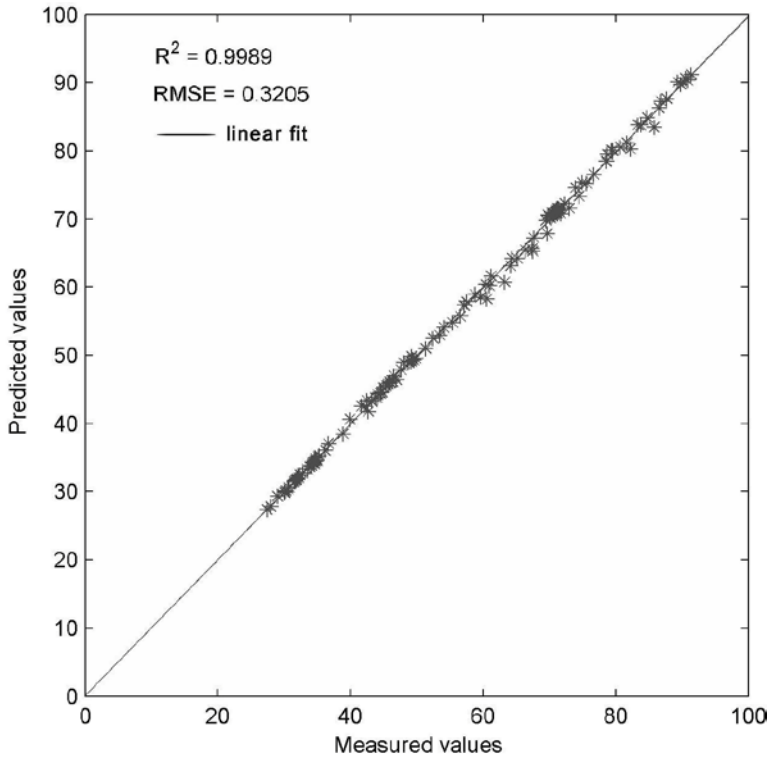

Figure 4. LS-SVM predicted vs. measured values of L* for the validation set.

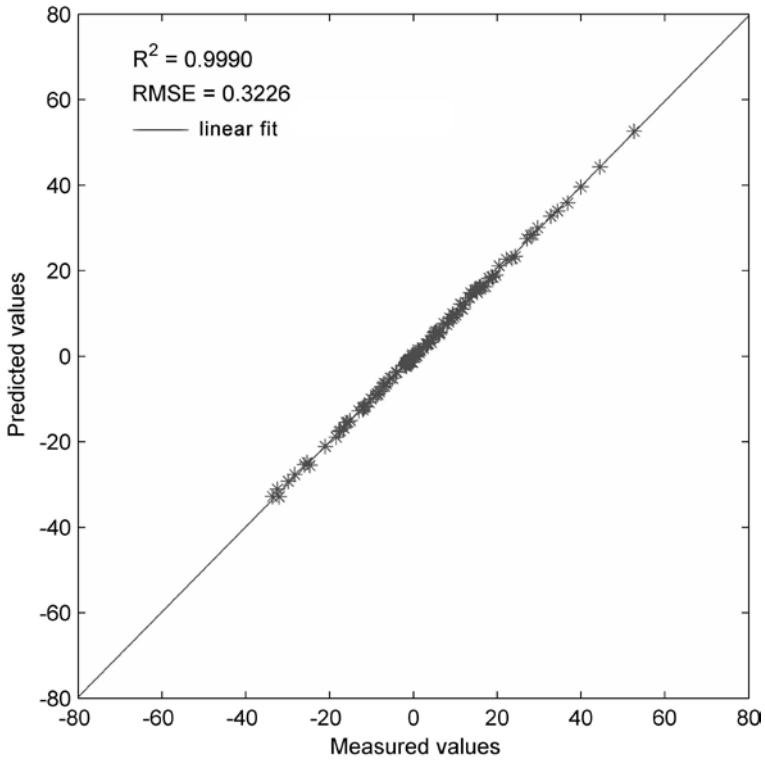

Figure 5. LS-SVM predicted vs. measured values of a*for the validation set.

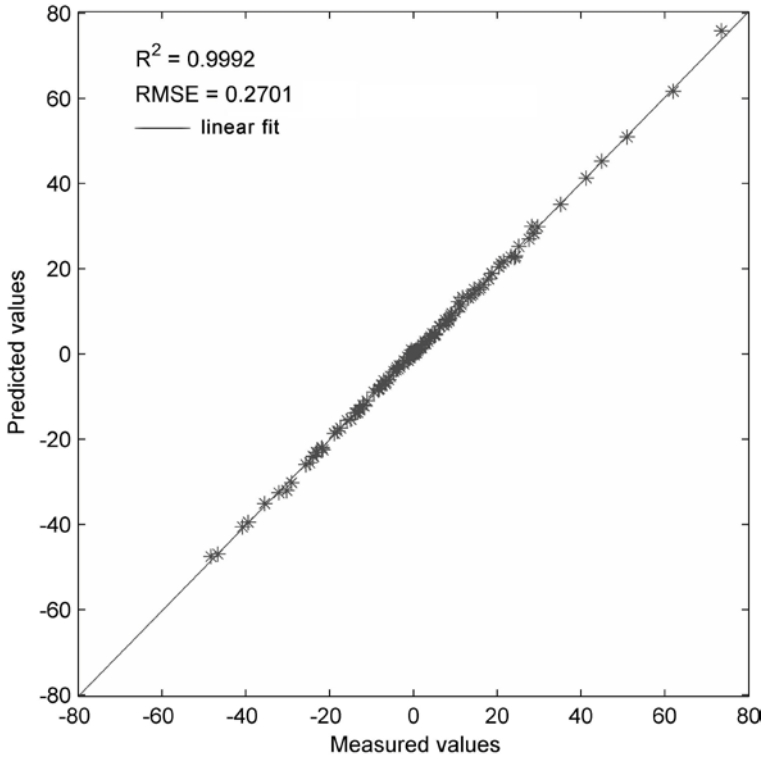

Figure 6. LS-SVM predicted vs. measured values of b* for the validation set.

Conclusions

The objective was to evaluate the potential of LS-SVM regression to solve the colour camera characterization problem in CVS. The results of this study shown that this approach produced high precision and accuracy in predicting the L*a*b*values from the RGB values generated by a CDC. Therefore, LS-SVM regression seems to be an useful tool to solve the camera characterization problem in the CVS and to use these systems for high-resolution L*a*b* colour measurements.

References

Hong G., Luo M. R., Rhodes P. A. 2001. A Study of Digital Camera Colorimetric Characterization Based on Polynomial Modeling. Color research and application, 26(1), 76-84.

León K., Mery D., Pedreschi F., León J. 2006. Color measurement in L*a*b* units from RGB images. Food Research International, 39(10), 1084-1091.

Liu F., Ye X., He Y., Wang L. 2009. Application of visible/near infrared spectroscopy and chemometric calibrations for variety discrimination of instant milk teas. Journal of Food Engineering, 93(2), 127-133.

Mendoza F., Dejmek P., Aguilera J. M. 2006. Calibrated color measurements of agricultural foods using image analysis. Postharvest Biology and Technology, 41(3), 285-295.

Suykens J., Vanderwalle J. 1999. Least Squares Support Vector Machines. Neural Processing Letters, 3(9), 293-300.

Valous N. A., Mendoza F., Sun D. W., Allen P., 2009. Colour calibration of a laboratory computer vision system for quality evaluation of pre-sliced hams. Meat Science, 81(1), 132-141.

Vapnik V. 2000. The Nature of Statistical Learning Theory. Springer-Verlag.

Wang D., Wang M., Qiao X. 2009. Support vector machines regression and modelling of greenhouse environment. Computers and Electronics in Agriculture, 66, 46-52.

Westland S., Cheung V., Connnah D., Ripamonti C. 2004. A comparative study of the characterization of colour cameras by means of neural networks and polynomial transforms. Coloration Technology, 120, 19-25.

Topic 5
"Logistics, food safety and traceabilily"

Poster Presentation

Application of NIR Technique for Food Safety Evaluation During the Grapes Delivery in the Cellar

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Abstract
The oenological sector is increasingly moving towards an improved quality of wines.
To meet this requirement can be useful, at least in large cellars, use of instruments potentially capable of providing real-time information on the grapes or the first products resulting from their processing. Knowing in real time the health status of grapes might allow the grapes to split into homogeneous groups and consequently choose the treatments to be carried out in winemaking.
The aim of this work is to verify the potential use of NIR technique (Near Infrared Spectroscopy) for the detection of some fungal diseases in grapes conferred in the cellar.
The research was set to three years. In the first two years the assessments were made in the laboratory on samples of grapes from the same vineyard, which differ only in a different level of fungal diseases (Botrytis cinerea and Uncinula necator). In the third year the tests were conducted in a large cellar with 2360 hectares of vineyards distributed in the province of Forlì-Cesena (Italy).
The laboratory evaluations on samples of grapes from the same vineyard were positives and they allowed to distinguish between the diseases and intensities of infection.
An equally positive response was not found in the cellar, where similar state of health did not provide comparable results. This result is probably caused by different environmental conditions of the vineyards (soil, orography, etc.) and it limits the application of NIR.

Keywords: Grapes, NIR spectrometry, food quality, diseases

Introduction

The Italian wine sector is increasingly moving towards better quality wines that also involves lower middle standards, produced in large wineries, representing over 60% of italian production.

The grapes in large cellars are subjected mostly to two tests: the sugar content and acidity.

Sometimes you can also have a visual analysis on health status, but this is a subjective outcome and as such it can be considered as purely indicative result. The assessment of the health state is undoubtedly one of the most important evaluations to differentiate the quality production and it would deserve a more secure determination.

An alternative methodology would be NIR spectroscopy, which has gained approval in oenology (Cozzolino, 2003, Liu, 2008) and other agroindustrial sectors. In these sectors, the NIR technique is considered easy to apply and rapid in supplying results and, most importantly, requires no sample preparation. This means it can be applied directly on the

production lines, providing data in real time, and great potential can be foreseen in the horticultural sector, where this non-destructive technique could be applied to characterize the quality standards of samples (Katayama et al., 1996; Williams and Norris, 1987, Caprara et al., 2009).

The aim of this research is to determine if NIR spectroscopy is an efficient method of quality evaluation for health status of grapes delivered to the cellar.

Materials and Methods

Laboratory tests

Laboratory tests were conducted over two years, 2006 and 2007, and samples were taken from farms in the area of Faenza (Emilia Romagna region).

The varieties Sauvignon and Chardonnais have been selected and several product samples were collected. The samples were differentiated by disease (Botrytis cinerea and Uncinula necator) and infection level. The following classes were established:

- 0, healthy product 100%
- 33, healthy product 66%, diseased product 33%
- 66, healthy product 33%, healthy product 66%, diseased product 33%
- 100, healthy product 0%, diseased product 100%

Three replicates were considered for each sample.

The grapes were pressed using a small manual press and the must was then filtered through a membrane of paper and collected in a glass beaker.

The spectrometer was a Bruker Optics Matrix-F, used with a probe for liquid samples in the NIR wavelength from 0.7 to 2.5 μ.

The probe was immersed in the beaker containing the sample, avoiding contact with the bottom of the container, and the data were sent and processed by a computer.

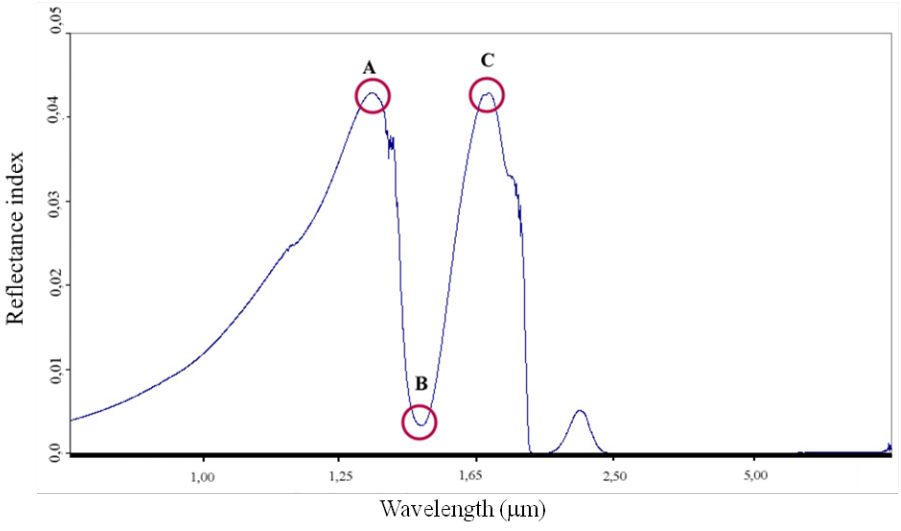

Figure 1. Spectrometric curve acquired with the NIR spectrometer (an example).

The NIR readings were evaluated by introducing an evaluation index calculated on the basis of equation 1 that utilizes characterizing points of the spectrometric curves (Caprara et al., 2009), in order to free the analysis from the absolute values of the individual readings (Fig. 1):

$$I = \frac{A - B}{B} \quad (1)$$

The data were analyzed using STATGRAPHICS software (StatPoint Inc., VA, USA). Analysis of variance (ANOVA) was performed on the data, considering storage time as main factor of analysis. The method used to discriminate among the means is Fisher's 95% least significant difference (LSD) procedure.

Tests in the cellar

The second part of the trial was conducted in 2008 at the "Cantina Sociale di Forli" on a day at the end of the harvesting period.

The analysis was performed on Trebbiano grape that is the most representative vine for the winery in question.

The samples were collected with a beaker from the tap of refractometric station where usually the tests were carried out.

For each sample were known the receiving area of the grapes, pH, Brix and health status assessed visually.

The evaluation was performed with the NIR with a probe for liquids with the same procedures adopted in the laboratory and using the same evaluation index.

The parameters considered as main factors of the statistical analysis are:

- health status (healthy product, diseased product)
- pH (higher values than average –lower values than average)
- ° Brix (higher values than average –lower values than average)
- Place of production (Valley – Hill)

The analysis was performed by comparing the evaluation index with the health status of the grapes and subsequently a multiple analysis of variance was performed considering as factors the health status coupled with one of the other three parameters (pH, ° Brix, place of production)

Analysis of the results and discussion

Laboratory tests

Laboratory tests, conducted under controlled conditions, gave indications of some interest.

Different samples from the same vineyard and with the same level of health showed the same absorption spectra.

In the presence of fungal diseases a lowering of maximum peak always occur, proportional to the level of infestation (Fig.2).

Statistical analysis done on the evaluation index revealed significant differences between the levels of infection and the diseases (Table 1).

Table 1. Multiple analysis of variance and mean values of evaluation index for the Chardonnais must in laboratory tests.

Effects		P-Value (observations = 33)	
Main effects	Grape deseases	0.0000	
	Level of infection	0.0000	
Interactions		0.0004	
Grape deseases	Level of infection	Evaluation index	
		Mean ± SE	Homogeneous groups*
Botrytis	100	9.82 ± 0.14	A
	66	10.13 ± 0.14	A
	33	10.83 ± 0.14	B
	0	11.69 ± 0.14	C
Oidio	100	10.89 ± 0.10	A
	66	10.84 ± 0.10	A
	33	11.00 ± 0.10	B
	0	11.54 ± 0.10	C

*Within each cultivar, means designated by the same homogeneous group letter were not significantly different based on Fisher's 95% LSD method.

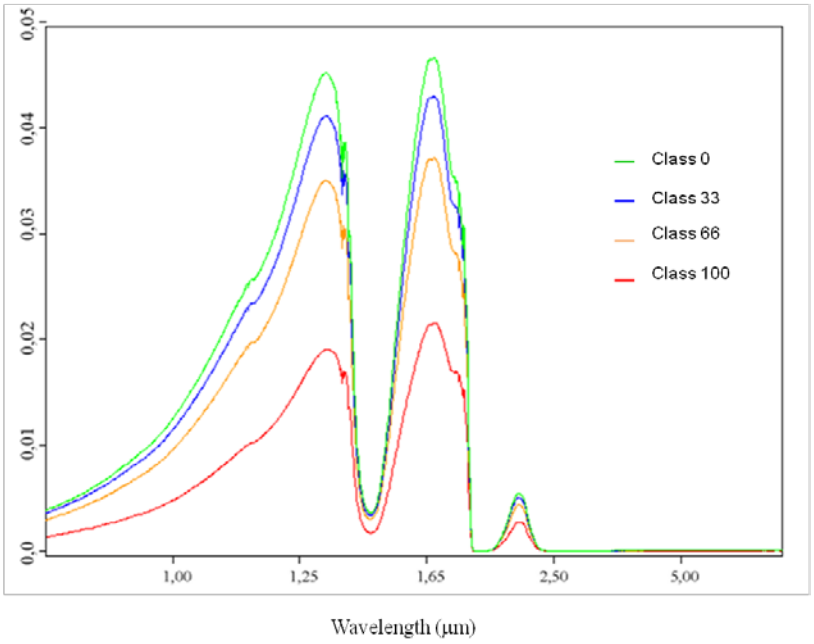

Figure 2. Spectrometric curve acquired with the NIR spectrometer for the Chardonnais must in laboratory tests. The curves show four classes of infection level for botrytis (0 - healthy product 100%; 100 - diseased product 100%)

Tests in the cellar

The 2008 weather conditions not adversely affected the health of grapes with maximum levels of infection reported mainly by botrytis (10%).

Table 2. Analysis of variance of evaluation index for tests in cellar.

Effects		Mean ± StE	P-Value (observations = 21)
Grape deseas	No	14.14 ± 0.39	0.70
	Yes	9.93 ± 0.37	
Place of production	Valley	9.89 ± 0.29	0.31
	Hill	10.59 ± 0.60	
° Brix	> 10.6	10.50 ± 0.36	0.09
	≤ 10.6	9.60 ± 0.34	
pH	> 3.6	10.30 ± 0.40	0.39
	≤ 3.6	9.83 ± 0.35	

The evaluation of the spectrometric curves, which in laboratory tests have shown considerable significance, not shows in trials in the cellar no difference between test samples with disease and healthy ones. This can not be attributed to the low level of found infection but it is due to the high variability of the samples. Indeed, even considering separately the two groups of samples (healthy and diseased), variability still remains high.

Performing statistical analysis, the evaluation index shows no significant difference (Table 2).

This behavior is repeated with a multiple analysis of variance considering as factors the health status coupled with one of the other three parameters: pH, ° Brix, place of production (Table 3). The only parameter that has a tendency to highlight differences ($p = 0.09$) is ° Brix.

Table 3. Multiple analysis of variance of evaluation index for tests in cellar.

Main Effects	P-Value (observations = 21)
Grape deseas	0.53
Place of production	0.27
Grape deseas	1.00
° Brix	0.09
Grape deseas	0.91
pH	0.45

Conclusions

The similarity of spectrometric curves recorded on the must with NIR has enabled a comparative evaluation by establishing an evaluation index obtained with two characteristic points of the curves.

Laboratory evaluations carried out on different grapes coming from homogeneous areas showed the ability of instrumentation to detect the presence of the disease and the level of infection.

The application in a real situation with heterogeneous grapes for place of production and mode of cultivation it has not the same capability to identify the diseased musts.

The analysis of correlations between the defined evaluation index and other characteristic parameters such as pH, ° Brix and place of production, shows no statistically significant differences in the same way.

The uncertainty in the results obtained in the cellar is due to the heterogeneity of samples from grapes grown in different climatic and pedological environments with cultivation techniques that are not always similar.

This result confirms the findings in other applications of NIR on fresh food, where the actual application of technology requires a very complex preparation which provides for the systematic acquisition of a large number of measurements on samples from fairly homogeneous areas of production.

In the case of grapes the issue proves even more complex because the variability may be higher due to various factors such as crop variety, clone, rootstock, etc., that make the masses of product to evaluate the more heterogeneous samples.

References

Caprara C., Martelli R., Pezzi F., *An application of NIR Technology to evaluate Potato Storage Time: first results*, XXXIII CIOSTA - CIGR V Conference "Technology and management to ensure sustainable agriculture, agro-systems, forestry and safety", 16-19 june 2009, Reggio Calabria (Italy).

Cozzolino D., Smyth H.E., Gishen M., 2003. Feasibility study on the use of visible and near-infrared spectroscopy together with chemometrics to discriminate between commercial white wines of different varietal origins. J. Agric. Food Chem.**,** 51, 7703-7708

Katayama K., K. Komaki, S. Tamiya, 1996. Prediction of starch, moisture, and sugar in sweetpotato by near infrared transmittance. HortScience, 31, 1003-1006.

Liu L., Cozzolino D., Cynkar W.U., Dambergs R.G., Janik L., O'Neill B.K., Colby C.B., Gishen M., 2008. Preliminary study on the application of visible–near infrared spectroscopy and chemometrics to classify Riesling wines from different countries. Food Chemistry, 106, 781-786

Williams P., K. Norris, 1987. Near-infrared technology in the agricultural and food industries. American Association of Cereal Chemists Inc., St. Paul.