

The use of TIC's as a managing tool for traceability in the food industry

D.B. Pinto ^{a,*}, I. Castro ^b, A.A. Vicente ^b

^a *Castro, Pinto and Costa, Lda., Rua Hintze Ribeiro, 585 - Sala 301, 4450-692 Leca da Palmeira, Portugal*

^b *Centro de Engenharia Biológica, Universidade do Minho, Portugal*

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Abstract

Food safety has become an important food quality attribute. Both food industry and authorities need to be able to trace back and to authenticate food products and raw materials used for food production to comply with legislation and to meet the food safety and food quality requirements.

PaniGest is a user-friendly computer package designed to manage traceability and help in the quality control and production improvement. This application was developed in Visual Basic language over an SQL database and its main features are: to register quality control parameters of raw materials, in-course products and final products; to manage reception, production and expedition orders; to analyse production costs, productivity, raw materials and products' consumptions; to trace products during the food chain. It runs on a personal computer over Windows 95/98 or Windows 2000/XP operating system. The program also uses common Internet Browsers to make information available to users.

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1. Introduction

In the recent years, new policies regarding food safety and food safety management were adopted by Governmental Authorities and Food Industry as a consequence of several food incidents and scandals. These incidents caused serious loss of confidence of the consumers that started to demand for high quality food, food integrity, safety guarantees and transparency. To answer these consumers requirements, quality assurance has become a cornerstone of food safety policy in the food industry that started to implement integrated quality and food safety management systems. These systems include all steps in food production chain namely the supply of raw materials, food manufacturing, packaging, transportation and logistics, research and development, maintenance of production equipment and training and education of staff. Increasingly, food quality is associated with a proactive policy and the

creation of requirements to maintain a safe food supply (Beulens, Broens, Folstar, & Hofstede, 2005).

Global food safety policies were adopted by Governments and a new series of regulations were created and adopted all over the World, with particular incidence in EC (European Community). One of the concepts introduced by these new legal documents was traceability. EC/178/2002 defines traceability as the ability to trace and follow food, feed, and ingredients through all stages of production, processing and distribution. This regulation is applied to all food industry. The Regulation contains general provisions for traceability which cover all food and feed, all food and feed business operators, without prejudice to existing legislation on specific sectors such as beef, fish, GMOs, among others. The requirement for traceability is limited to ensuring that companies are, at least, able to identify the immediate supplier of the product in question and the immediate subsequent recipient, with the exception of retailers to final consumers (one step back/one step forward). Traceability is the ability to track back a product and its history through the whole, or part, of a

* Corresponding author. Tel.: +351 9143 11262; fax: +351 22 992 20 36.
E-mail address: danielpinto@cpc.com.pt (D.B. Pinto).

production chain from harvest through transport, storage, processing, distribution and sales or internally throughout the production stages. Traceability is a generic issue, as its fundamentals are independent of the type of product, production and control system it serves (Kim, Fox, & Gruninger, 1995).

Traceability and Food Safety Management systems can work properly based on pen and paper versions but they are time and resource consuming which makes them difficult to implement in small and medium companies where the resources are scarce. Moreover, the International Standardization Organization (ISO) also started to work on the adaptation of the Quality Management Systems standard to the food industry ISO22000, which is currently on the final draft.

The use of new technologies of information and communication to support and facilitate the practical implementation of these complex systems is very recent and, until now, it can be found only in larger food production units. The development of adequate computer packages to reduce the paperwork involved in the management system can be extremely helpful for SME's.

In the baking industry, the traceability process is very complex due to the diversity of raw materials used and the large number of different products that a single batch can generate. Moreover, at the end of production process, there are several finishing raw materials used in the product that, usually, are not controlled or even traced back to the supplier. Therefore, the development of a computer application, using a user-friendly interface, specially designed for small and medium food companies, was pertinent. PaniGest was created to respond to these needs integrating some legal requirements such as traceability with quality control, production management, raw material and finished products stock control, consumptions, production costs and HACCP systems.

2. Materials and methods

2.1. Database development

Planning the database structure is one of the most important tasks when developing a computer application once all the information required will be stored in and related by the database. Depending on the model used, the information can be related in different ways. Early models included the hierarchical model (where files are related in a parent/child manner, with each child file having at most one parent file), and the network model (where files are related as owners and members, being that each member file can have more than one owner). Relational databases offer many advantages over unstructured forms of data storage (Codd, 1970; Harrington, 2002). Through the use of indices and other optimizing devices, speed gains for searches may be considerable. Moreover, redundancy and therefore storage space are minimized. Also, data is handled by a single computer which is easily backed up and/or mirrored by a second computer (Bradley, Masca-

rob, & Santhakumara, 2004). Another important advantage of relational databases is the ability to rapidly summarize data with a small number of commands, usually using the structured query language (SQL). With a few of these commands, one rapidly obtains a comprehensive overview of a data set, something that could otherwise take many hours programming. But, perhaps the most important advantage of relational databases is that they impose a consistent data format (Bradley et al., 2004).

The major issue in database development is to find a database structure that is broad enough to be applicable in several industries and, at the same time, adequate to consistently structure data. The relational database model was a huge step forward, because in order to relate any two files or records, they simply need to have a common field, which makes the model extremely flexible. The relational database model, being a table-based structure, naturally groups data conditions according to type or product. For example, there might be tables containing lists of products, raw-materials, users, formulations and quality control data. One or more additional tables would store production data, and a final table would serve as a hub linking production data to product and raw-material data. By means of cross references, the complete traceability of raw-materials to final clients as well as users actions associated with any production could be derived from the database, without reference to external sources.

The production stages and the records needed during the production process under analysis (baking process) had to be studied in detail in order to develop the database that records all the relevant information to achieve total traceability of the product and, simultaneously, manage paperwork. Fig. 1 presents the production flowchart that was used to develop the database.

The conclusions of the production flowchart analysis were that the traditional baking industry produces a wide range of products (bread and cakes), ready to be sold, based on the same batch of ingredients. This process becomes even more complex when more than one of those batches is made during the day. Moreover, the difficulty increases during expedition of final products to the client because different ready to sell products originating either from the same batch or from different batches are very often delivered to the same client and, in many cases, the client is the final consumer.

The developed database is a relational database and Fig. 2 exemplifies some of the multiple relationships established between tables.

For example, the field "Order" in "Table_RM_Orders" table is related with the field "Order" in "Table_RM_Rows_Orders" table. In this particular example, the first table should hold suppliers order data and the second table records the multiple lines of the supplier order. The type of relationship is a one-to-many relationship because a supplier order could have multiple lines of different products. Multiple relations such as that described above are developed and implemented in this database.

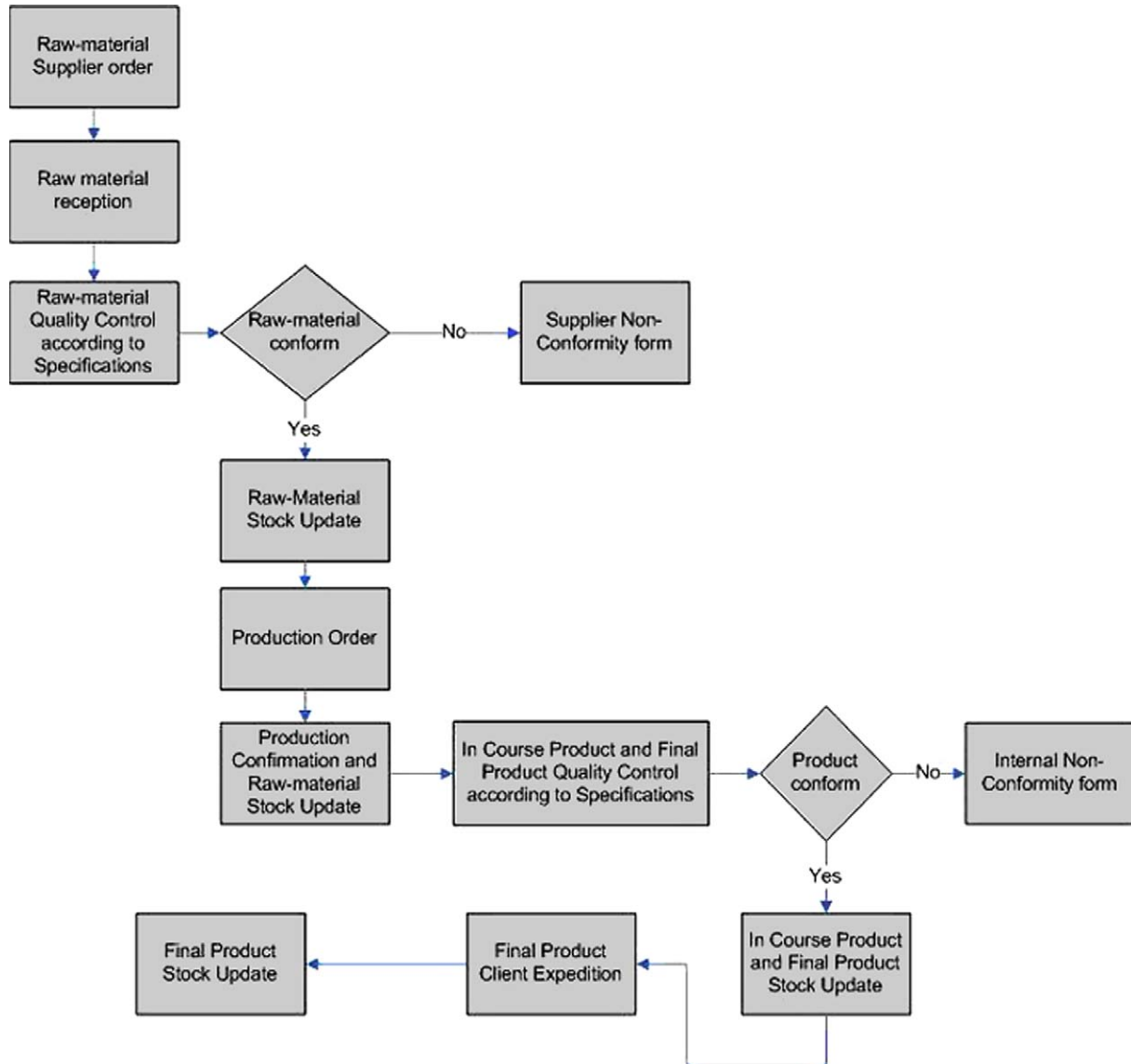


Fig. 1. Baking process flowchart.

Initially the database was developed in Microsoft Access and then was updated to SQL Server. The Access version of the application was maintained in order to reach clients that are unable to install in their units an SQL Server. There are several advantages when using a SQL Server database instead of a Microsoft Access database. For example, some of the codes written in SQL language, used to query the database, can be integrated directly into the SQL Server database using Store Procedures thus making the application lighter. Also, if the Client suggests some program changes, it is much easier to update the Database without making another program executable (file extension.exe). This makes the file lighter and if there is the need of change concerning queries to database it is much easier and there is no need of re-design the program code. Another important advantage is data security, integrity and user access control, which are considerably better in a SQL Server Database.

2.2. Interface development

PaniGest is supposed to be used by several departments within the Organization thus is extremely important that the interface is user-friendly.

This computer program package was developed using Visual Basic 6.0™ by Microsoft® under a Microsoft® Windows® operating system (e.g. Windows 95/98 or Windows 2000/XP). A comprehensive, rapid application development environment, Visual Basic helps developers to quickly create and deploy client/server applications, and to program easily for the Internet using familiar Visual Basic programming tools and techniques.

The application also uses commonly known ActiveX controls and some Dynamic Link Library (DLL) from Microsoft. A DLL is a library for applications within the Windows operating system as well as for programming and contains one or more functions that are compiled,

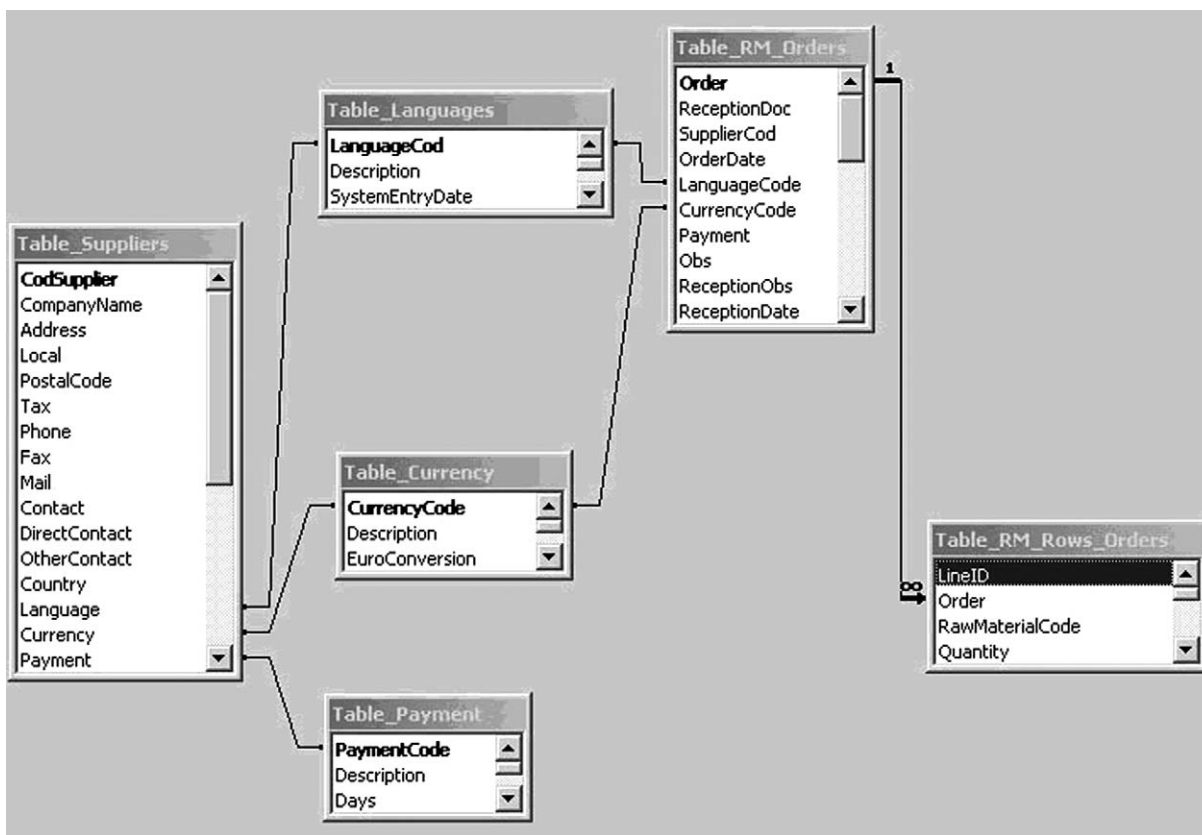


Fig. 2. Database relationships.

linked, and stored separately from the applications using them (Takeuchi, Yadohisa, Yamaguchi, Watanabe, & Asano, 2002). However to support some of the present application's functionalities several DLL's had to be developed.

2.3. Error handling

One of the major concerns in software development is the error treatment and handling. PaniGest error handling concerned two major types of errors: the common and usual user errors (e.g. typing letters in instead of numbers) and the database operations errors. For the database operations errors the transaction methodology was used. Being so, in any database operation, such as inserts, updates and deletes, the program executes all the code and then verifies if an error has occurred; if there are no errors, the transaction is committed, otherwise it is rolled back. The main advantage of this methodology is that it assures data integrity, avoiding the insert, update or delete of partial data. This is commonly known when the SQL instruction is made over two or more different database tables. For example, in Fig. 2, the field "Order" in "Table_RM_Orders" table is related with the field "Order" at "Table_RM_Rows_Orders" table. As referred above, the first table holds suppliers order data and the second table records the multiple lines of the supplier order. Using the transaction technology, for example, when changing a raw material supplier order, there is no risk at all of updat-

ing the table that holds supplier data and not updating the table that holds the multiple product order lines. It either updates everything or it does not update anything at all.

This type of code is written as in the following example where cpcOT is the variable that stores the link to the database. If an error occurs while executing the SQL instruction, the program jumps to the "Erro:" function and stops and rolls back the SQL instruction that was already executed. This is demonstrated in the following error handling code example:

```

On error goto ErrorHandler
cpcOT.BeginTrans
SQL Instruction
ErrorHandler:
If Err = 0 Then
    cpcOT.CommitTrans
    Err.Clear
Else
    cpcOT.RollbackTrans
    Err.Clear
Exit Sub
End If

```

Another important measure to control errors is the implementation of an error sub-routine in any user action. If an error occurs a message to the user is generated. In background, the application records the occurred error in

the database table for future analysis and correction. This is of extreme importance because it allows the authors to implement corrective actions in future updates of the application. Moreover, when a connection to the Internet exists, error messages can be sent to the author (by e-mail) for immediate analysis. In some cases it is possible to implement corrective actions through Internet connection.

2.4. Outputs

Considering the application of this computer package to Food Safety Management Systems it was fundamental to create easy-to-read output documents or pre-defined reports. Seagate Crystal Reports was used to develop all the output documents. To access the database, Seagate Crystal Reports uses an Open Database Connectivity (ODBC) connection. ODBC is a widely accepted application programming interface (API) for database access. It is based on the Call-Level Interface (CLI) specifications from X/Open and ISO/IEC for database APIs and uses Structured Query Language (SQL) as its database access language. Data Sources ODBC is used to access data from a variety of database management systems.

Another important feature is the browser access to the information which makes it possible to query important information such as product specification, using a simple computer with Internet browser installed.

3. PaniGest®

PaniGest main features are: to register quality control parameters of raw materials, in-course and final products; to manage reception, production and expedition orders; to analyze production costs, productivity, raw materials and product's consumptions; to define and print labels containing lot information and other relevant data; to implement traceability back and forward in the food chain (from raw materials to the final client).

In order to maintain total traceability (back and forward) different types of internal lots were implemented (auto-numbers): the internal lot for raw-material; the lot of finished products and the daily production reference. The use of these auto-numbers (internal lots) will be explained further in the text. When the application starts, it opens its main form where the user can access multiple options and menus. Several of those options and menus correspond to table management (example: VAT codes). These data, introduced firstly in the program, are indispensable for the subsequent actions. Other options and menus, explored further ahead, are the operation and control options and menus, such as the raw-material section, production section, quality control section and final product section.

3.1. The main form

The requirements for software vary according to the goals of its users. In the food industry the level of computer

skill and computer access varies widely among users, and this is usually related to their responsibilities in the whole process. These responsibilities are even more important when a safety and quality management system is implemented and maintained within the organization. For all users it would be more effective if the computer program interface could be changed according to the user's level of computer proficiency and authorization level. For novice users, complicated input and output options are confusing and often result in users missing the objective of the program, and also may result in errors in operation. Dismissing unnecessary options and simplifying the interface, therefore, would be of great benefit to this type of users. Using graphics, such as charts, figures, and diagrams to represent the results of analysis is often more effective than a numerical description. Also different responsibilities related to filling down registries or validate them; release orders, recall procedures and so on are established within an organization with a defined hierarchy related to the existing quality management or HACCP systems. Being so, the software was developed using a friendly interface to all users and with user-level authentications (Fig. 3). It also allows multiple users to access the program simultaneously. However, a safety measure was implemented during development: it is impossible to use the same user name simultaneously in different workstations. After entering the user name and password, the software executes a Store Procedure with a database query to upload the user permissions and validate the user log in. A DLL was developed by the authors to automatically import user and computer name from the Windows Operating System. This DLL is of extreme importance not only because it limits access to the users but also because it can be used as a "signature". With this feature, it is possible to audit all the users operations and to determine responsibilities.

After the user log-in, the main form (Fig. 4) contains a lateral menu with the different sections of the computer package: Raw-materials; Production; Quality Control; Finished Product; Clients Definitions; Tables; Utilities; Lists and Software Configuration. This lateral menu was made using an OCX control called vbaccelerator Explorer Bar Control available at the vbaccelerator web site for download. It can also open a "Status Form" showing the actual status of supplier's orders, production orders, raw-materials expiration dates and current stocks. All the options available in the lateral menu also exist at the upper menu of the main form.

Inside each main menu sections there are sub-menus opening inside the main form (MDI form). This type of construction allows the left menu to be always available. All sub-forms of the program open inside the main form.

3.2. Raw-materials section

The raw-materials section is the startup section of this program as in a real industry production context. It is used to execute supplier's orders, reception of raw-materials and



Fig. 3. User log-in.

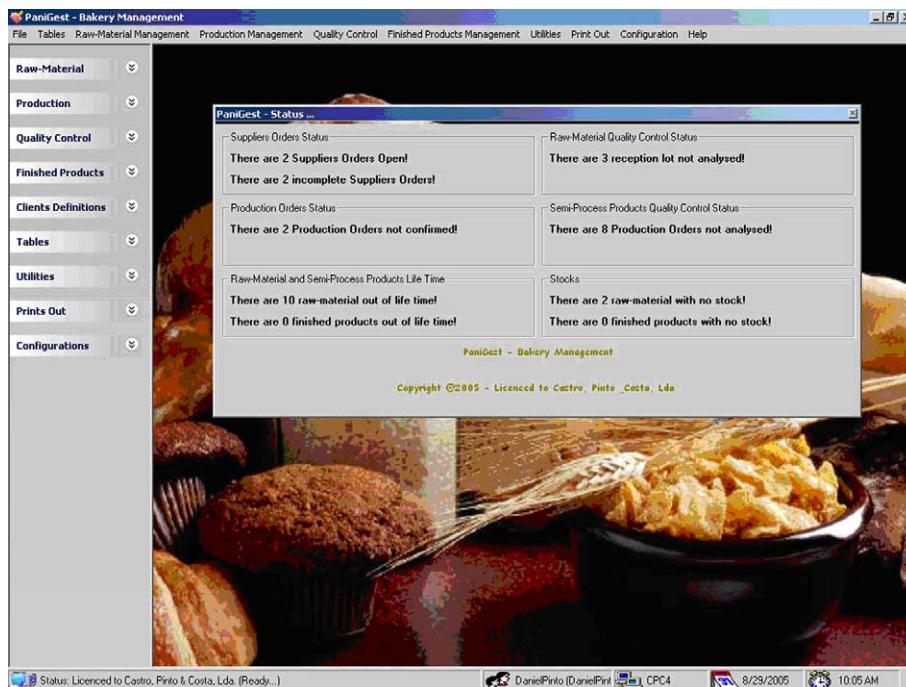


Fig. 4. Main form.

raw-materials stock control. Specifications of raw-materials are extremely relevant to HACCP systems so the application is prepared to fill in raw-materials forms. In this form all the relevant data, namely microbiological and organoleptic data, are recorded as well as acceptance/rejection criteria. Moreover, suppliers information, costs, average costs, minimum and maximum stocks are also defined under this section. When inserting a new raw material, the user can activate the option that forces that raw-material to pass by a quality control check, on reception. Further ahead, the quality control section will be explored and explained.

Perhaps the most important feature of this section is the raw-material reception (Fig. 5). This is made automatically

by the attribution of a sequential number, the reception number (RN), by supplier lot which is the first internal lot (auto-number). To easily guarantee the raw-materials traceability it is advisable to attribute a new number (auto-number) for each supplier lot even if it corresponds to the same delivery (order form). Furthermore, this sequential number will be used to maintain traceability and stocks.

3.3. Production section

It is in this section of the program that data of in-course and finished products can be introduced. In food safety systems it is important to define internal specifications for the products in order to control the production. The program

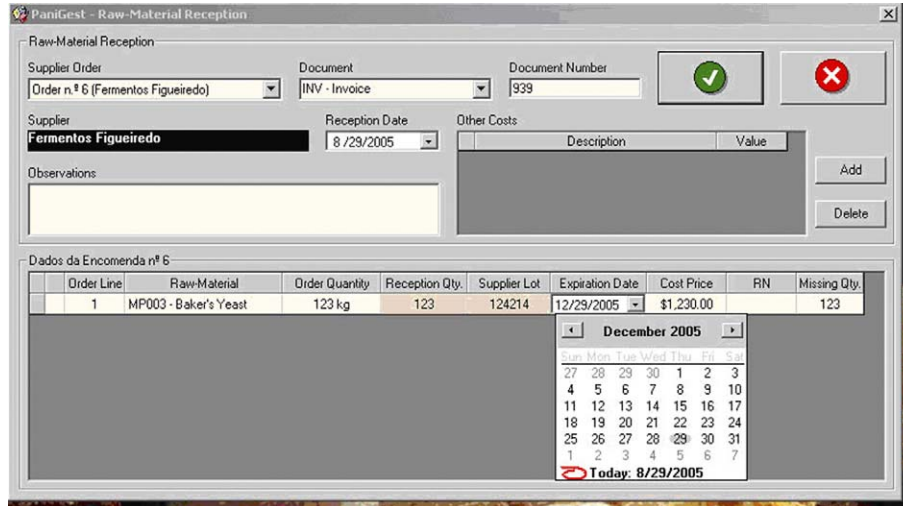


Fig. 5. Example of a raw-material reception.

has forms for on-course and final products, including the insertion of product’s formulations as well as different final products derived from the same formulation (example: 1 kg bread, 0.25 kg bread). Similarly to the raw-material section, it is possible to define whether a product goes or not through a quality control stage before expedition.

Production orders (Fig. 6) automatically indicate the raw-materials type, quantity and suggest the raw-material internal lot to be used as well as define the lot number

(auto-number). The suggestion of the internal lot is made by a very complex algorithm that calculates raw-materials distribution according to FIFO (First in – First out) and expiration dates. It also considers quality control blocked raw-material lots. If there are not enough raw-materials an error message will be generated with the information of the missing quantity of the raw-material in question. The production order is a printable output used by the production section as a registry (Fig. 7).

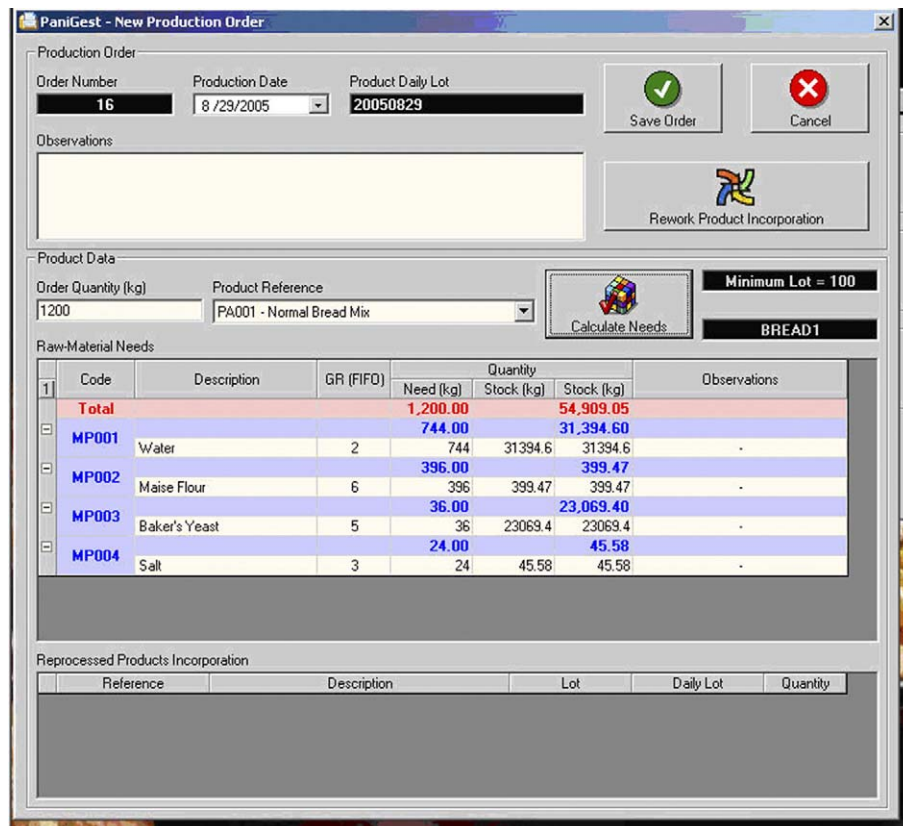



Fig. 6. Example of a production order.



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Production Order

Number: 15

Production Order		7/16/2005
Reference: PA001	Description:	
Lot: 20050716	Preview Quantity: 1,200.00 kg	
Daily Lot: BREAD1	User: DanielPinto	
Order Observations: -		

Raw-Material					
Code	Description	Quantity (kg)	GR	GR Used	Real Quantity (kg)
MP001	Water	744.00	2	_____	_____
MP002	Maise Flour	396.00	6	_____	_____
MP003	Baker's Yeast	36.00	5	_____	_____
MP004	Salt	24.00	3	_____	_____

Reprocessed Products			
Reference	Description	Quantity (kg)	Lot - Daily Lot

Fig. 7. Pre-defined report output for production order.

The production operator should write down in the referenced paper form the exact quantity of the used raw-materials and the correct internal lot when there are changes to the original order. The lot number of a final product consists of two different parts identifying the production date (code 1) and the product code (code 2), respectively. If more than one batch of a given product is produced in the same day the lots will be identified sequentially (20050225 BREAD1, 20050225 BREAD2, for example). The lot codification is defined by each company where this program is installed and implemented.

PaniGest is also prepared to incorporate and trace back re-worked products, which is an extremely difficult task in the food industry (e.g. leftovers from the previous day) in a production order. This option allows tracing back re-worked products that were used in a specific production order and, consequently, identify any problems related with the use of leftovers in a fresh product. After confirmation of the exact raw-material consumption the production manager closes the production order. It is at this time that raw-material stock movement is finally saved and the product becomes available to the quality control (if this option is activated at the configuration section). In this section it is also possible to run production simulations in order to preview raw-material consumption thus allowing managing supplier's orders. All simulations that are made and saved may be printed out.

3.4. Quality control section

All the data and documents that a Quality Control Department involves are implemented and can be gener-

ated by the program. The main goal of this section is to document quality control operations namely acceptance/rejection decisions, release procedures, printing technical analysis bulletins, among others (Fig. 8). The quality control is made according to the specifications that were inserted simultaneously with the insertion of a new raw-material or product. A security measure was implemented: there only can be stock movement and updates when the quality control result is conform. If there is a non-conformance, a non-conformance form (internal or to the supplier) can be generated and printed. As referenced before, the program has an algorithm to block a raw-material lot by an authorized user. If this happens, the specific raw-material becomes unavailable for movement and consequently for production.

Traceability is, perhaps, the most important feature of the application and runs as a sub-section of quality control. Two types of traceability queries can be made: traceability to final products (Fig. 9) and traceability of raw-materials.

In the first case, the user inputs the final lot of the product (code 1 or code 1 plus code 2) and all the information of traceability is displayed in a tree form (Fig. 9). The displayed information (for code 1 input) is distributed by the following sections: the daily production references; the product and production data; specifications and quality control results; the raw-materials (and lots) that were used in the production; the quantity of each raw-material that was used; the specifications and quality control results of each used raw-material; the finishing (if applicable) raw-materials used; in-course products used; the re-worked products that were used and those who have been generated within this production. It is also possible to trace if

On-going Raw-material Analysis

RN	Reception Date	Raw-material	Supplier	Quantity
7	9/3/2004	MP005 - Sugar	RAR - Refinarias de Açúcares Reunidas	100 kg (Kilogram)
10	9/6/2004	ME001 - Boxes	Castro, Pinto & Costa, Lda.	1 Unit (Unities)
11	2/12/2005	MP001 - Water	SMAS Viana do Castelo	12 kg

Resultados da Análise à Guia de Recepção número 7

Specification	Value	Lower Limit	Upper Limit	Result	OK
Visual Analysis	OK	OK	OK		<input type="checkbox"/>
Foreigns Bodies	Absent	OK	OK		<input type="checkbox"/>
Moisture	10	8	12		<input type="checkbox"/>

Analysis Observation

Select All

Save Cancel

Fig. 8. Raw-material quality control form.

Finished Products Traceability

Production Lot: 20050716

Lot: 20050716 - 7/16/2005 - Registered by DanielPinto

- Produced Daily Lots
 - BREAD1 - PA001 - Normal Bread Mix (Produced at 7/16/2005, expiration date of 7/18/2005)
 - Product Data
 - Expiration Date - 2 dias
 - Finished Product Specifications
 - Visual Analysis - OK
 - Raw-Material
 - Reception number 2 - MP001 - Water (Supplier Lot: N3o tem)
 - Quantities
 - Previewed Quantity: 744
 - Real Quantity: 744
 - Specifications
 - Foreigns Bodies - Absent
 - Raw-Material Quality Control
 - Foreigns Bodies - Ausencia - Número Análise: 2 (9/3/2004)
 - Reception number 6 - MP002 - Maise Flour (Supplier Lot: 11111)
 - Reception number 5 - MP003 - Baker's Yeast (Supplier Lot: CJF0012)
 - Reception number 3 - MP004 - Salt (Supplier Lot: 212131)
 - Finishing Raw-Material
 - Re-Worked Products
 - Production Data
 - Previewed Quantity: 1200
 - Real Quantity: 1200
 - Observations: -
 - Finished Product Quality Control
 - Visual Analysis - OK - Número Análise: 28 (7/16/2005)
 - Client Expedition

Fig. 9. Traceability form example.

the product was released and sold and if so who was (were) the client(s) it was sold to. If the user inputs a raw-material lot the finished products lots where that particular raw-material was used are displayed.

Recall procedures have to be made concerning two major objectives: to minimize the economical losses and to guarantee safety. Being so, the more specific the records are, the fewer products need to be recalled. However, this

has to be done as quickly as possible. Using PaniGest, it is just a matter of seconds to find out where the product is and to segregate it or to recall it.

3.5. Final product

Finally, the final product must be finished and delivered to the client. In this section there is the possibility of finish-

ing products (for example when a product is packaged). It is also possible to query the final product stocks, to make expeditions and to query product stocks movements. According to EU legislation traceability must be possible also to the final client. In order to achieve this requirement, with this program expedition can be made either to single clients or to pre-defined routes (a very common feature in baking industry). A pre-defined route consists of a group of clients, usually in the same geographical location, with standard quantity and products orders. If this is the case, the user inserts the route at the client definition section and at the expedition moment, the program, once again, suggests the lots of products to be supplied (using FIFO) and the user just has to confirm the lots and the quantity.

3.6. Other sections

Under Tables section, useful information can be stored which will be used by other sections. Some examples are payment conditions; type of documents; VAT taxes; languages; types of currency and measuring units. The Utilities section is used to activate, inactivate or re-activate clients, suppliers, raw-materials and products.

4. Conclusions

The developed computer package, PaniGest, is currently under testing in several Portuguese baking industries. So far, the feedback has been good, specially because it reduces the amount of paperwork and allows to clearly identify responsibilities. Also, the application allows implementing traceability in the food (baking) industry without a large number of technical and human resources and it facilitates recall procedures with economical and safety

benefits. The generated outputs are also important records in case of an Audit.

PaniGest is very user friendly, specially because it runs under a common Microsoft Windows environment and uses common computer user controls. Another important advantage is the use of a web browser to easily query information by users who do not need the program installed on their personal computer. It is designed to meet the needs of the food industry, specifically baking industries, merging production management, food safety management and systems with regulatory requirements.

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