The integrated management of food processing waste: the use of full-cost method for planning and pricing Mediterranean citrus by-products

Vergamini Daniele[1], David Cuming[1] and Davide Viaggi[1]

[1] University of Bologna/Department of Agricultural Sciences, Bologna, Italy
daniele.vergamini@unibo.it

Paper prepared for presentation at the 3rd AIEAA Conference
"Feeding the Planet and Greening Agriculture: Challenges and opportunities for the bio-economy"

25-27 June, 2014
Alghero, Italy

Summary

The new technologies in the field of food processing provide the opportunity to revive some productions that are crushed by the global market and environmental issues. However in the citrus sector the lack of investment and difficulties to manage economic cost are likely to slow down the take-off of these innovations. Starting from the results of the 7FP European Project NAMASTE, this paper provides a methodology for the computation of the full cost of several citrus by-products and an attempts to analyse through a simulation model the decision making problem of a citrus firm who decide to upgrade citrus waste in order to obtain several by-products. The results show the importance of using the full cost in the management of resources. However, the possibility of producing from citrus wastes are constrained by production capacity resources and by the overall efficiency of production technologies. The economic sustainability can be achieved by an increases in production efficiency, improving the technologies and the ability to reuse waste. However, a large amount of investment is still required, which only the large firms can support, at least in the short term.

Keywords: food industry by-products, full cost accounting, citrus by-products.

JEL Classification codes: (Times New Roman 10)

The integrated management of food processing waste: the use of full-cost method for planning and pricing Mediterranean citrus by-products

Vergamini Daniele[1], David Cuming[1] and Davide Viaggi[1]

[1] University of Bologna/Department of Agricultural Sciences, Bologna, Italy

1. INTRODUCTION

Since the mid-1980s, the world production and consumption of citrus has grown rapidly. According to FAOstat (2010), the estimated production in 2010 was around 124 million metric tons, of which more than two thirds is concentrated in China, Brazil, Mediterranean countries, the United States and India. It is an extremely competitive market, where the Mediterranean citrus producers account for about 20% of world citrus production and about 60% of world fresh citrus trade (FAO stat, 2010). Moreover, in the Mediterranean basin, the three most important varieties of citrus, from an economic perspective (oranges, mandarins, lemons), are prevalent, constituting a valuable reservoir of genetic resources for breeding and commercial purposes (Lacirignola and D'Onghia, 2009).

Despite their importance, over the last few decades the major (traditional) Mediterranean fruit producers have gradually been losing their competitive edge in the realm of fresh citrus fruits and processed citrus products, both from foreign and domestic markets (Brendenberg, 2004; Baldi, 2011).

On one hand, this loss can be attributed primarily to the increase of labour costs (Brendenberg, 2004) in traditional producer countries (i.e. Spain, Italy), along with the progress of emerging countries characterised on the contrary by low cost workforces. The low labour cost is a necessary condition to maintain the competitive advantage in the fresh products market. This is likely the most important factor considering that citrus fruits, mainly oranges and small citrus fruits (tangerines, clementines, mandarins) are in most cases handpicked. In addition to the labour factor, an inefficient use of the processing technology has also contributed to the reduction in the competitive advantage of those Mediterranean industries that have failed to adapt to market changes.

On the other hand, given that there has been a change in consumer trend in the trade of processed citrus, particularly in the form of an increasing focus on the quality and the value-added aspects of the product, the required continuous investments in technology, production capacity and high standards are lacking in most of the cases. Moreover, changes in lifestyle and especially in consumption (e.g. the increase in nutritional standards in developed countries, the expansion in world trade of high value food products, the evolution of consumer preferences toward more small-sized, easy-peeler and seedless fruits) have led to a change in the targets of fruit and vegetable production, with particular reference to citrus. There has been an increase in demand for processed products which has resulted in a progressive reduction in the availability of citrus to the fresh market which was previously the natural outlet of the traditional producers.

The change in production has taken place together with the development of numerous technological advances in processing, storage and packaging. These improvements have allowed the increase in the range of citrus produced, in the product convenience, the healthfulness and the quality of citrus fruit juices. Moreover, this pattern has led to a rise in production costs and often decreasing availability of raw materials (Laufenberg et al., 2003).

The scarcity of raw materials has motivated the significant recourse to imports, contributing to increases in processing costs and decreasing advantages compared with rivals where fresh product is more plentiful. In the globalised market, since crop size affects the amount of fruit reaching the processing industry, a reduction in crop size, or difficulties in expanding production, can cause a loss of competitive advantage. In some traditional EU citrus producing countries difficulties have been encountered in attempts to expand production compared with emerging ones, hence the increases in imports.

In order to assure a continued long-term activity as citrus producers and processors, the Mediterranean industries need to sell all the products and by-products obtainable from the fruit at a competitive price (Bredenberg, 2004). To meet this objective, they need to focus on recovering, recycling and upgrading by-products in order to obtain higher value and useful products (Laufenberg et al., 2003). This can also contribute to the reduction and prevention of the pollution caused by the generation of large volumes of waste, both solids and liquids that the food and food processing industries produce.

In recent years there has been a wide spread of studies and research in the field of food and by-product recovery (i.e. see the next section). The EC-funded FP7 project NAMASTE-EU (New Advances in the integrated Management of food processing wAste in India and Europe: use of Sustainable Technologies for the Exploitation of by-products into new foods and feeds, Joint EC & DBT-India call: KBBE-2009-2-7-02: Valorization of by-products in food processing) represents a purpose of research in this innovative field. The objective of the project was to develop new processes for the integrated conversion of citrus by-products into new high value products or raw materials for the food and feed industry. With this objective, different procedures have been assayed and a final single multipurpose process providing alternative routes have been implemented through the research activities. The innovative character of NAMASTE lies in the protocols developed to obtain the citrus by-products, namely citrus fibre and polyphenolic extract, high pressure homogenization (HPH) paste and cloudy agent.

If these new technologies are considered from a citrus firm's perspective, the choice to invest or not on the recovery of the waste in order to obtain high value products raises the need for an economic evaluation of the by-products full cost. In such way, the amount of waste produced, can be considered as a new additional capacity resource, where the costs of its management and uses must be accounted in order to derive the profitability of the new products. Thus, the full costing facilitates the making capacity and pricing decision (Balakrishnan and Sivaramakrishnan, 2002).

The purpose of this paper is to develop and test a product-mix model to solve the capacity planning problem of a citrus processor who decides to bio-convert citrus waste into a set of by-products. The model is a mathematical programming model that integrates full cost data of citrus by-products (citrus fibre and cloud agent), maximizing the firm profit for each optimal product mix level. The allocation of the capacity resource and the price configurations obtained through the application of this methodology may have potential for the management of medium-sized food processing companies. As there is no application of the Full Cost Method in the literature about the upgrade of vegetable residues for the production of multifunctional food ingredients in fruit juice and bakery goods, the paper can be taken as a primer for future development in the direction of assessing the economic sustainability of such innovative technologies.

The remainder of the study is organized as follows. The next section provides the background literature on the citrus by-product recovery processing industry. Section 3 describes the methodology adopted, followed in section 4 by the results of a case study and in section 5 by a discussion. Concluding remarks are provided in section 6.

2. CHALLENGE FOR THE CITRUS FOOD INDUSTRY

From the huge amount of world-wide citrus production, only one-third of the crop is processed (Marín et al. 2005). The processing fruit are mainly oranges, followed by lemons and grapefruits. The target of food industry is juice, but also, marmalade, segments of mandarin and flavonoids and essential oils are produced respectively from the canning and the chemical industry (Izquierdo and Sendra, 2003).

In accord with Cohn and Cohn (1997) and Marín et al. (2005) the amount of residue obtained from the fruits accounts for half of the whole fruit mass. Consequently, the food industry produces large volume of solid and liquid wastes. According with Laufenberg et al. (2003), Mamma et al. (2008) in the past CWs often have been dried and used as raw material for pectin extraction or used without treatment for the production of animal feed or as fertilizers. However in the last few years, the increasing costs associated with the storage and transportation of CWs and the lower price obtained from feed markets have resulted in a loss of attractiveness of the industry to these uses. At the same time, the necessity to prevent environmental pollution as well as the need to conserve energy and raw-materials has grown and new methods and policies for waste recovery, bioconversion and utilization into more useful, high-value products have been introduced (Martin, 1998; Laufenberg et al. 2003).

Creating a secondary use for the CWs through the upgrading of citrus by-product can be considered as a strategic element for the reduction of wastes and for the optimization of the use of the resources.

Therefore the manufacturing industry has to consider the potential economic and ecological benefit of this green productivity (Laufenberg et al. 2003). The objective must be a strategic management to increase product quality and safety, efficiency, environmental aspects through the development of bio-innovations. In this perspective it could be a challenge for the citrus producers and processors. This objective could be fulfilled by different strategic approaches which vary from the optimization of the process, to closed loop production design and bio-conversion of CWs into high-value product for energy, food and bio-chemical industries.

Several research groups have been working in the development of multifunctional ingredient from citrus by-product and CWs. Laufenberg et al. 2003 provide a list of innovative products obtainable from the upgrade of CWs. These products includes dietary fibres, as an excellent source of flavours, dyes and antioxidants or as ingredient in beverage and bread industries, as well as bioadsorbents, pectin, phytochemicals, gellin and stabiliser agents (Henn and Kunz, 1996). Streenath et al. (1995) analysing the utilisation of citrus by-products as a clouding agent, influencing the texture (enrich or adjust the cloudy appearance) and viscosity in beverages. The organoleptic and chemical properties of CWs offer a widespread use in healty and functional drinks and selected fruit juice (Laufenberg et al. 2003). Furthermore the CWs could be use through an enzymatic, cellulolytic, pectinolytic hydrolysis or microbial conversion to obtain liquid biofuel (Widmer and Montanari, 1995; Grohmann and Bothast, 1994). Following Pourbafrani et al. (2010), Wilkins et al. (2007), Stewart et al. (2005), Gunaseelan (2004) and Mizuki et al. (1990), CWs, which contains different carbohydrate polimers, are an interesting sources for production of biogas and ethanol.

With a research target mainly focused on the exploitability for beverages, food and feed industries, evaluating the real possibilities to bring to the market the research products, also the NAMASTE-EU project can be placed in this wide literature. Following this purpose the by-products (citrus fibre, cloud agent and HPH paste) and process resulting from the project, were analysed through an environmental and economic assessment, providing an evaluation of the industrial relevance (Fava et all. 2013).

3. METHODOLOGY

The Full Cost Method (FCM) was selected from management accounting theory for the computation of citrus by-product production costs. The FCM allows determining the cost of a product related to the revenue it generates. The full cost configurations obtained through the application of this costing system allows achieving theoretically optimal product mix decisions using decision rules that simplify the capacity-planning and pricing problems. Dewan and Magee (1993) argue that the value of accounting allocations lies in the ability to decompose complex problems through simple decision rules that can be informationally very demanded even in small firms.

Focusing on the capacity planning issue of a citrus processor firm, in this paper it is examined the role of cost allocation in influencing managerial decision through a simple one-period model of a firm who bio-converts products' wastes into new by-products.

This approach takes its cue from the comprehensive literature review provided by Balakrishnan and Sivaramakrishnan (2002), while it differs by introducing the possibility of reuse a part of the utilized production capacity in terms of “wastes to produce new products”. In the first part of the methodology is explained the allocation process, while in the second part the model is introduced.

Balakrishnan and Sivaramakrishnan (2002) define the full costs of a product as an estimation of the long-run incremental costs to produce an additional unit that accounts for all of the variable costs[1] plus the allocated capacity resource costs[2]. According to economic theory, full cost might not be the right metric for addressing short-term planning problems due to the uncontrollability[3] of capacity resource costs (i.e. fixed cost are sunk when pricing decions are made).

However, despite the considerable criticism and its recognised limitations, the FCM it is still widely used to make product and capacity planning decisions (Zimmerman 1979, Cohen S.C. and Loeb M. 1982; Govindarajan and Anthony 1983; Miller and Buckman 1987; Shim and Sudit 1995; Cooper and Kaplan 1998). According to Balakrishnan et al. (2012), firms allocate fixed costs mainly for valuing inventories and for computing income, for product and resource planning and to help managers to induce desired organisational behaviour. Furthermore, the evidence that firms allocated an amount of the fixed overhead to

[1] According to Cinquini L. (2008), variable costs vary based on production volumes (e.g. raw material, labor, utilities, and delivery costs). Usually those costs can be directly related to the cost object (e.g. units of a product). However in some cases (e.g variable overhead costs) the variable costs are not traceable to a specific product and an underlying activity (e.g. machine hour) is needed to allocate them to the product (Balakrishnan et al., 2012).

[2] According to Balakrishnan et al. (2012) the resource costs or capacity costs are often known as fixed costs. In a decision alternative these costs are unavoidable in the short term due to the discrete time lag between when the cost has been claimed and the benefit will be recognized. For this reason it is often difficult to trace these costs to a cost object, even without committing an error in the computed product costs.

[3] Often, in the evaluation of decision alternatives there is a distinction between controllable and uncontrollable costs. The first are those costs that will be avoided if this alternative is not chosen. The second are those costs whose value will not change, relative to the status quo, if the decision maker chooses the alternative.

obtain the product's full cost to make a comparison between different product alternatives has been proven by Govindarajan and Anthony (1983), Shim and Sudit (1995) and Cooper and Kaplan (1998).

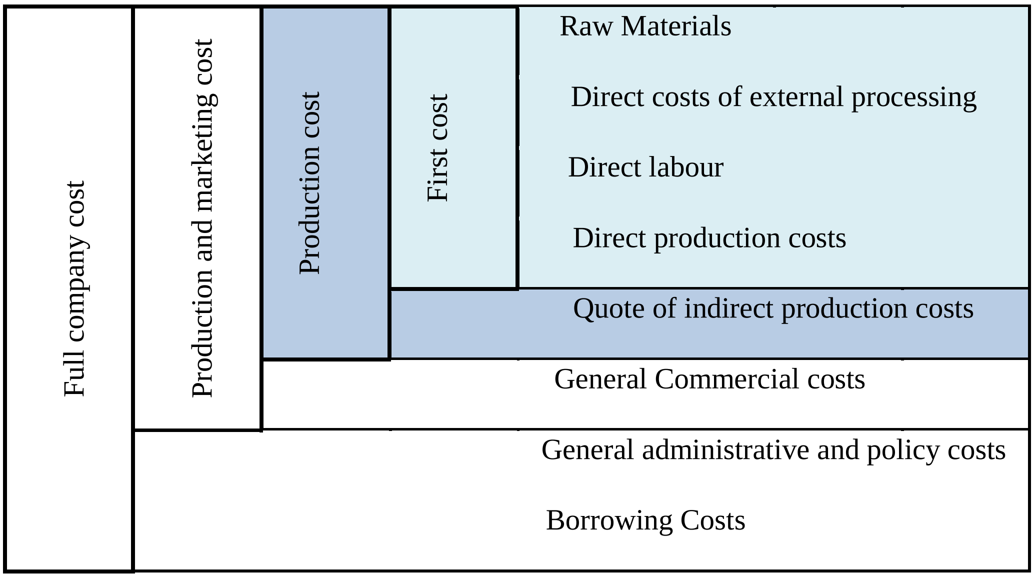
The FCM is based on the principle of full cost absorption (Cinquini L., 2008) for which all of the resource costs must contribute to the determination of the full cost of the object of calculation (i.e. the final product that caused a certain percentage of both the fixed and variable expenses the firm incurred). This principle involves the problem of the allocation of common and special costs, which are not directly traceable to the products, and thus the identification of a suitable basis for the allocation.

If the special costs are those costs that are constituted by the value of inputs the services of which are used exclusively by the object of cost, once the object of cost has been decided the special costs can be referred to in an objective way, measuring the value of the quantity of production factor effectively consumed by the object multiplied by the unit price. However, common costs are those costs of factors used simultaneously by more cost objects for which it is difficult to distinguish the specific quantity of consumed factor (Cinquini L., 2008). Accordingly, common costs should be allocated to the object of cost by way of an allocation procedure.

Addressing the issue of common costs, the FCM provides a reasonable measure of the opportunity costs of the possible alternative uses of the shared resources used in manufacturing the products. More in detail, with the full cost method it is possible to calculate the cost of each product from the indirect production cost, which is normally generated from different processes that use the same equipment (Cinquini L. 2008, P. Miolo Vitali 2009).

Fig. 1 shows the product cost configuration, according to Cinquini L. (2008), which highlights four different areas related to different cost pools. The first cost includes raw materials, direct costs of external processing, direct labour and direct production costs (operating cost). The production cost includes in the first cost a share of indirect production cost, which together with the general commercial and administrative expense represent the full company cost.

Figure 1 Cost product configuration (source: Cinquini L., 2008)



Source: own elaboration

The calculation of a product's full cost differs significantly among firms, depending on sector of activity (manufacturing, commercial, service provision etc.) and the type of production process. These factors can affect the identification of the cost pool, necessary for the cost allocation, particularly for the distinction between direct costs and overhead costs that should be allocated according to cost driver units (machine hours, Euro/labour hours, etc.).

According to Cinquini L. (2008), there are two types of FCM: single basis and multiple basis depending on the number of allotments involved in the calculation. Considering the single base FCM, the economic literature provides the follow processing steps:

1. Choice of the indirect cost elements (capacity costs, overheads, production and structure) to aggregate in costs pools, according to cost aggregation criteria;
2. Choice of the cost driver units (labour hours, machine hours, Euro/labour hours, etc.). This phase is the most important, and also the most criticised (Balakrishnan et al., 2012). In this phase the proportionality of the volume of indirect costs is determined with respect to the allocated object of cost, which varies depending on the base;
3. The allocation coefficient is calculated by determining the ratio of the cost pool to the total of the relevant driver unit;
4. Determine the share of overhead costs to be attributed to the cost object, multiplying the allocation coefficient for the relevant cost driver that refers to the product;

Recovering the notation developed in Balakrishnan et al. (2012), a formalised structure of the allocation system within the FCM is provided in the following.

Consider a firm that supplies an amount of capacity resources J (labour hours, tonnes of raw materials, machinery hours, etc.) at some cost per unit of capacity. K are the cost objects (i.e. the cost associated with the developed products) and according to Banker and Hughes (1994) and Datar and Gupta (1994) a linear production function is assumed. For j=1 to J let CC_j represents the capacity resource costs associated with each resource supplied with TCC=$\sum_j CC_j$. Other costs, such as variable costs, are voluntarily excluded in the explanation due to the relative ease with which they can be assigned to the final cost object (e.g. units of product). Thereafter, L represents the different cost pools CP_l (i.e. different cost aggregations). Each cost pool contains a certain proportion of resources j, according to cost aggregation criteria. CD_{lk} define the number of cost driver units (e.g. labour hours) that connect the consumption of cost pool l by cost object k. In an allocation problem, the selection of drivers is based on the assumption of proportionality between cost drivers and cost objects. Furthermore, to complete the cost panel and derive the production cost of each product, it is necessary to allocate the quote of indirect production costs that have been aggregated in cost pools, for each cost object k (e.g. each of the k product developed).

Let $\varphi_{lk}=\frac{CP_l}{\sum_k CD_{lk}}$, with φ_{lk}>0 represents the allocation coefficients that it are obtained as the ratio of cost pool to the total of the relevant driver units. Then, in a FCM costing system, the costs allocated to the cost object k (e.g. the products) are $CO_k = \varphi_{lk} CD_{lk}$ for k=1 to K.

Once the allocation process is complete, the sum of the common costs (including the indirect costs) and the special costs (direct costs) is divided by the quantity of the product generated for each process, hence defining the product's full cost. Such estimation can be useful to complete the economic analysis with an assessment of the profitability of the by-products. Given that the profitability of the by-products depends on the size of the process that affects the optimal quantities, a sensitivity analysis has been carried out on the amounts of processed waste in order to take into account the possibilities and the constraints for adaptation of the firm. Assuming that the firm's objective is the maximization of profits, to assess the optimal product-mix levels, a one-period mathematical programming model has been developed.

The model considers a citrus juice processor that produces by-products from CWs (e.g citrus fibers, cloud agent etc.). It is hypothesized that the firm is "price taker" with fixed capacity in the production of the principal goods, while at the same time, since the by-products market it is a new market, the firm can determine the prices basing on its marginal productivity, making an estimation of the potential market demand.

Furthermore, the ability to use wastes to produce by-products is considered as an increase in production capacity. The firm makes N products using T resources in fixed proportion, where $T=\alpha T+(1-\alpha)T$ states that the firm used a share α of the resources to obtain the juice and produces a certain amount of wastes $(1-\alpha)$ that recover and reuse for the production of citrus fibre and cloud agent. Assuming linearity in the use of the capacity resource j, with j=1 to J to produce the i products, with i=1 to I, a Leontief production function is assumed.

Following the notation provided in Balakrishnan and Sivaramakrishnan (2002), let v_i be the variable cost per unit of product i, and let k_i be the variable cost per unit of product i obtained from citrus waste, and let each unit of products i uses m_{ji} units of the capacity resource j.

The firm can consume S_{ji} units of resource j to produce the by-products, with $S_{ji} = (1-\alpha)T$ that represent the additional resource capacity acquired from the reuse of wastes. However the firm must pay a cost to exploit wastes, represented as $\theta_j>0$ for all j. Let x_i be the amount of by-products produced.

Since in the production of the principal good the firm is price taker, on the contrary in the production of the by-product the firm can influence demand by changing prices. As a consequence the firm has more degree of freedom in managing opportunity costs in the production of by-products.

Let $x_i=(A_i - w_i)/B_i$ be the linear demand function for the production of by-product, where $A_i, B_i > 0$ state respectively the potential size of the markets and the elasticity of the demand, which has been estimated by the firm on the basis of its marginal productivity for production of the by-products. $w_i = (A_i - B_i x_i) \geq 0$ represents the inverse demand function determines the by-products price.

As a result of the hypotheses above, the Model takes the following structure, given a fixed value of the production capacity resource (T) and maximizing the gross margin (GM):

Max

$$GM=(w_i - k_i)x_i + (P_i - v_i)qT-\theta_j \quad (1)$$

Subject to:

$$x_i \leq \sum_j^J m_{ji} S_i \qquad \forall i, \tag{2}$$

$$w_i, P_i, x_i \geq 0 \qquad \forall i. \tag{3}$$

Where:

Equation (1) is the objective function (Gross Margin). Equation (2) provide the resource feasibility constraints. At the end of the optimization process it is assumed to find different by-product mix for each level of capacity resource used, and different price level according to the different production costs and on the basis of the inverse demand function.

4. CASE STUDY AND RESULTS

The methodology described in the previous section was implemented through a case study carried out in two steps. The first step concerns the full cost analysis of the NAMASTE technologies, while in the second step, with the results of the analysis a simulation exercise for two NAMASTE by-products was run. The model was built in GAMS, it simulates a planning and pricing problem of a citrus juice firm who decides to recover and bio-convert citrus waste in order to produce citrus fibres and cloud agent.

The full cost analysis of the NAMASTE by-product has regarded the citrus fibre and the polyphenolic extract, a high pressure homogenization (HPH) paste and cloudy agent. The innovative nature of the NAMASTE by-products lies in the protocols developed, even though some of which (e.g. citrus fibre and cloud agent) have been widely produced by the processing industries. Dietary fibre represents the indigestible polysaccharides and oligosaccharides found in fruit, vegetables, grain and nuts. The citrus fibres can be as matrices for flavours, dyes or antioxidants (Laufeberg et al., 2003). The soluble and insoluble dietary fibres have beneficial effects on human health and can be designed for application in bread or beverages. Furthermore the peel cloud, also known as clouding agents (CA), represents an agent that can increase turbidity and provide a natural appearance of a fresh cloudy fruit juice.

The economic analysis of the NAMASTE process was carried out at an industrial level in order to make a comparison with existing market products. On one hand, since the NAMASTE project was a research project, all the relevant information and data about the protocols were acquired from the laboratory results (i.e. quantity of processed by-product, raw materials, processing time and waste produced). On the other hand, to scale up the products to an industrial level several hypotheses have been done. The scale up strategy first requires to assume the production objectives for the three analyzed process, which identify the size of the hypothetical processing plant in terms of the processed amount of by-product (in tons/year), then several hypothesis were formulated to determine the amount of labour, the raw materials consumption, the duration of production processes and the machineries required for the processes. Furthermore, an exhaustive interview was carried out to the Namaste industrial partners to seek clarification and to obtain an accurate basis upon which to calculate processing costs. Data about the annual yield production of the plant, the number of employees, processing time and processes phase as equipment name, model number and brand name with other specifications was sought for the calculation process. In addition all the relevant and available cost information was acquired from the partners, while it should be noted that the collection of comprehensive data can be difficult given that private sector industrial partners need to respect internal policies regarding the privacy of industrial data. Table 1 report an example of the screening table submitted to the research team for HPH process.

Table 1: Equipment List for HPH Paste (source: own elaboration)

Phase	Equipment name	Model number	Brand name	Other info
Freeze-drying	Freeze-dryer	Ray™ 150 or Conrad™ 500 (depending on quantities)	Gea Niro	Ray™ 150: Input capacity: 3500 kg/24 h Output capacity: 500 kg/24 h Conrad™ 500: Input capacity: 1000 kg/ h Output capacity: 500 kg/ h ~ 12000 kg/h
Grinding	Grinding	1042 series granulizer	MPE	Grind size: 4,700 - 100 microns Max Capacity: 20000 kg/h Total Power:15 - 22 kw
HPH treatment	High Pressure Homogenizer	Ariete Series	Gea Niro	Capacity: 1800 L/h Motor Power: 110 kW Water use: 120 L/h
Packaging	Plastic bags			

Source: own elaboration

On the basis of the information acquired, it has been formulated the hypothesis of a citrus processing plant who exploits the three NAMASTE protocols. It was hypothesised that annual citrus by-product volume was approximately 72,000 tonnes to be allocated as an input into several alternative production, which are enumerated below: a) 50% Fibre 50% Cloud; b) 50% Fibre 50% Paste; c) 50% Cloud 50% Paste; d) 100% Fibre; e) 100% Cloud; f) 100% HPH Paste. The first three hypotheses represent combined production alternative in which are analysed only two processes for time. The other points involve the production of only one product for time. Furthermore it has been hypostasized that in the scenario A, a fibre fraction can be also obtained as a by-product during the production of cloud. Whereby working approximately 36,000 tons of by-products to produce the cloudy agent, of these about 19% (6,808 tonnes) have been re-used for the production of fibre.

According with industrial partners it was hypothesised a continuous production process that lasts for 253 days/year and 8 h/day, which allows a distribution of the workload over the year, while in reality the citrus industry operates seasonally. Generally, citrus products are processed over a 4-6 month period; during the rest of the year the plant activities are focused on either loading or unloading of raw materials or equipment maintenance. The hypothesis mirrors the reality while at the same simplifying the cost computation as it allows for the inclusion of the production cost of equipment maintenance periods and the cost of loading and unloading of raw materials. Furthermore it has been hypostasized that the citrus plant were to employ 6 workers (full-time), as follows: 3 Technicians (30,000 euro/yr), 2 Warehouse workers (30,000 euro/yr), 1 Marketing staff (58,000 euro/yr). Moreover it is assumed a payback time o 6 years for initial investments.

Once these hypothesis was defined the full cost analysis was undertaken by way of the following steps: a) Classification of the acquired costs; b) Identification and separation of common costs from special costs; c) Selection of the basis for the cost allocation; d) Allocation of common and indirect costs to the final products; e) Calculation of the full unitary costs (citrus fibre, cloud and HPH citrus paste).

In Table 2 below, the computational steps required for the allocation of capacity cost are provided for the first scenario. Furthermore, for ease in the exposition, the computation of variable overhead costs has been ignored, because these costs can be assigned to cost objects with relative ease.

Table 2: FCM scenario 1, firm data input (source: own elaboration)

Panel A: Data on Costs

Total factory overhead	€ 2,701,229
Total general overhead	265,000
Total overhead	€ 2,966,229

Panel B: Data about Volume and Labour consumption (Cost driver unit)

	Fiber	Cloud	Total
DLH	7,084	5,060	12,144
(Staff unit per Labour consumption hours per work day)			
Yeld production	3,142	2,340	5,482
(t/year)			

Panel C: Allocation of Cost Based on Direct Labour Hours

Overhead rate= € 2,966,229/12,144=€ 244.25 per labour hour (rounded)

	Fiber	Cloud	Total
Total cost to product	1,730,300	1,235,929	2,966,229

Panel D: Allocation of Cost Based on Yield Production

Overhead rate= € 2,966,229/5,482=€ 541.02 per labour hour (rounded)

	Fiber	Cloud	Total
Total cost to product	1,700,233	1,265,996	2,966,229

Source: own elaboration

Panel A of table 1 shows the overall capacity costs for the firm; Panel B provides details about the volume and the consumption of labour hours by each of the firm’s two products. The firm has € 2,966,229 in manufacturing overhead costs and expects 12,144 labour hours. Therefore an overhead rate of € 244.25 per labour hour is determined by the rate of overall capacity cost and labour hours (= €2,966,229/12,144 labor hours). The allocation of cost to the fibre product is computed by the product of the overhead rate and labour hours (=€ 244.25 per labour hours X 7,084 labour hours); similar computation apply to the other products and for the other scenario.

The results of the full cost analysis of the NAMASTE processes for the scenarios A, B, C are reported in Table 3 below. The full cost per unit (Euro/kg) is reported as ratio between the sum of the total direct costs and the overall capacity costs (allocated according to the scheme and assumptions set forth in the previous paragraph) and the amount of by-product processed to get each final product.

Table 3: Results of NAMASTE processes for the scenario A, B, C (source: own elaboration)

SCENARIO	Allocation criteria	Fibre unitary cost (Euro/kg)	Cloud unitary cost (Euro/kg)	HPH unitary cost (Euro/kg)
A. 50 % Fibre 50 % Cloud	Direct labour hours	6.88	4.01	
	Yeld Production	6.87	4.02	
B. 50 % Fibre 50 % Paste	Direct labour hours	7.07		4.27
	Yeld Production	6.36		4.28
C. 50 % Cloud 50 % Paste	Direct labour hours		4.15	4.27
	Yeld Production		3.51	4.28

Source: own elaboration

There were no significant differences in the three cases analysed that justify the choice of an allocation policy based on volume rather than another one based on the amount of labour consumed. The cost for the dietary fibre and cloud agent can be compared with the reference market prices of 6 EUR/kg for fibre and with a range between 1 EUR/kg to 4.785 EUR/kg for cloud (data provided by the NAMASTE industrial partners). In the scenario b, the price of the fibre is closer to the market using as allocation criteria the volume of processed by-product. In case C, the full unitary cost of cloud agent, still referring to the second allocation option, is lower and widely between the market range. The reference price for the HPH paste was 1.85 EUR/280 g. Based the information obtained from the Namaste research team, a hypothetical packaged product contains approximately 84 g of paste (in a product weighing 280 g, not including packaging). Outside the product costs related to promotion, transportation, mark-up etc., the approximate cost of the actual reference product becomes 1 EUR (or slightly less). Accordingly, the paste must not cost more than 0.30 EUR/84 g as it must substitute around one third of the reference product. The results referred to in Table 4 shown that for hypotheses B and C the cost for the paste is only slightly higher than the cost of the similar ingredient in the reference product (i.e. slightly vary from 0.35 EUR to 0.38 EUR/280 g).

Table 4 provides the results of the last hypothesis D, E, F considering separately the production of Fibre, Cloud and HPH paste.

Table 4: Results of NAMASTE processes for the scenario D, E, F (source: own elaboration)

SCENARIO	Fibre unitary cost (Euro/kg)	Cloud unitary cost (Euro/kg)	HPH unitary cost (Euro/kg)
D.100% Fibre	7.07		
F.100% Cloud		4.13	
F.100% HPH Paste			2.85

Source: own elaboration

In the scenario D, according to our calculation, the Namaste price for fibre was quite high (7.07 Euro/kg) since the market price for dry fibre is 6 EUR/kg. However in the case F, the price for the HPH paste is significantly lower compared to the results of the combined alternatives (i.e. scenarios A, B, C).

In the second step, taking the results of scenario A, was then applied the mathematical programming model. The one-period model hypothesizes a citrus juice firm who decides to exploit the citrus waste (i.e. mainly pulp, membrane and peel), obtained from the extraction of the citrus juice, to produce the citrus fibre and the cloud agent. According with the literature, it has been assumed that the total processed citrus fruit provides about the 60 percent of citrus juice, while the remaining 40 percent represents the raw material to produce the new by-products.

The relevant information about by-product costs has been taken from the full cost analysis of scenario A. The price for the citrus juice has been fixed on 2 Euro/lt, based on the average of the current market prices, which range from 1,74 Euro/lt to 2,40 Euro/lt for the organic juices. It was assumed that the marginal revenue for the juice production is about 1.40 Euro/lt of product, excluding the cost of packaging, marketing and transport. Hypothesizing that the firm can process more than the 72,000 tonnes of CWs of the scenario A, it was chosen to perform a broad sensitivity analysis on the total amount of processed citrus fruit (i.e. the total resource capacity) to evaluate different production scenarios in terms of product mix, prices and costs.

Thus, the problem become a planning decision problem about how much of the new capacity resource (e.g. CWs) can be allocated between the by-products production. In other words, the choice of the optimal combination of by-products that maximizes the overall profit.

Assuming that the citrus firm maximizes the profit resulting from the production of juice, fibre and cloud, the results of the optimization carried out are summarized in Tables 5 and in Figure 1 and 2.

Table 5: Results of NAMASTE model for scenario A (source: own elaboration)

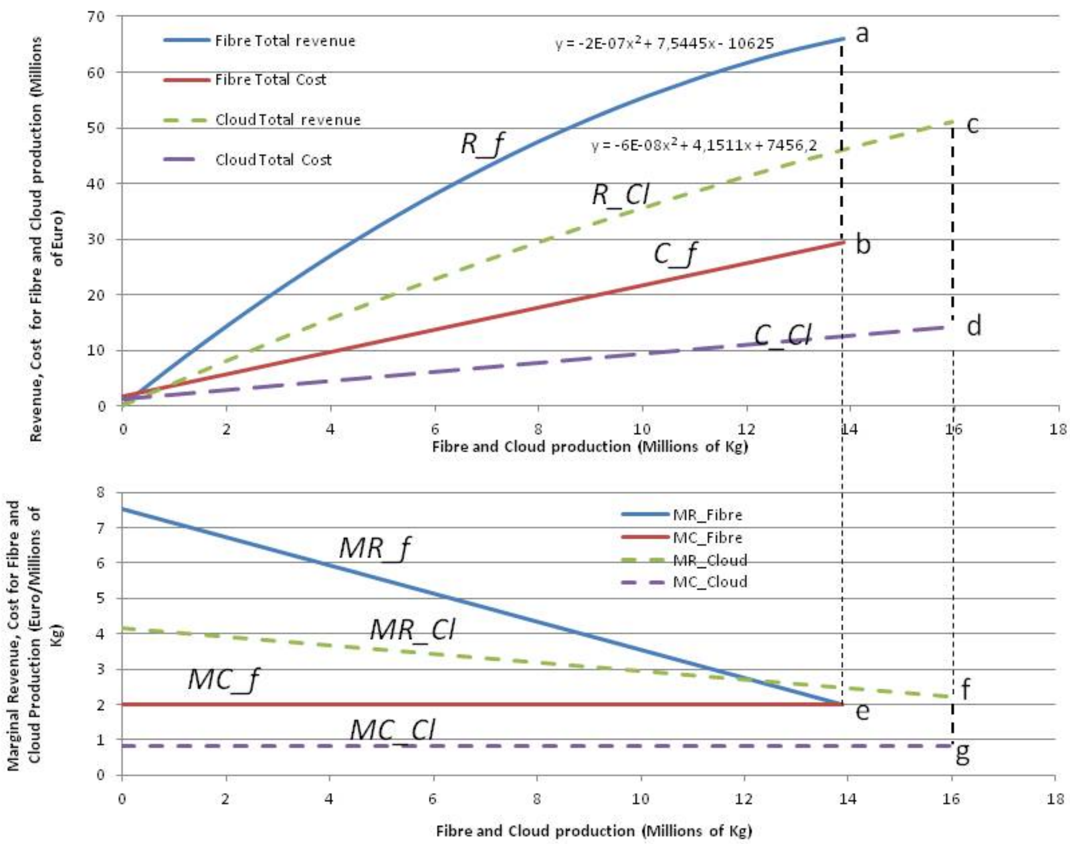
Processed citrus fruit (kg)	Gross Margin (Euro)	Fibre production (kg)	% Fibre/CWs	Fibre price	Cloud production (kg)	% Cloud/CWs	Cloud price
0	-1,730,300.68	0	0	0	0	0	0
10,000,000.00	9,141,868.52	452,917.9	4.52	7.45	598,756.59	5.98	4.12
30,000,000.00	30,043,715.4	1,240,178.13	4.13	7.29	1,884,561.33	6.28	4.04
70,000,000.00	71,204,538.55	2,837,526.44	4.05	6.97	4,439,173.16	6.34	3.89
130,000,000.00	13,1327,215.50	5,319,370.99	4.09	6.47	8,207,187.65	6.31	3.66
200,000,000.00	198,949,437.90	8,483,314.36	4.24	5.84	12,403,310.23	6.20	3.41
260,000,000.00	254,416,359.10	11,947,147.12	4.59	5.15	15,440,134.68	5.93	3.23
350,000,000.00	330,757,563.30	13,872,250.00	3.96	4.76	15,949,296.48	4.55	3.20
400,000,000.00	372,757,563.30	13,872,250.00	3.46	4.76	15,949,296.48	3.98	3.20
600,000,000.00	540,757,563.30	13,872,250.00	2.31	4.76	15,949,296.48	2.65	3.20

700,000,000.00	624,757,563.30	13,872,250.00	1.98	4.76	15,949,296.48	2.27	3.20

Source: own elaboration

In Table 5, following the sensitivity analysis carried out for the total amount of processed fruit (millions of kilograms) are reported the Gross Margin for each production scenario, the amount of fibre and cloud produced, the relative costs and prices. In the first row assuming that the firm does not produce, the negative profit indicates the amount of fixed costs required to start the production of citrus fibre and cloud. Furthermore, the share of quantities produced of fibre and cloud is growing, but at different ratios depending on their marginal costs. In addition, for each level of resources the cloud production is higher than fibre. However, considering the sensitivity analysis conducted on the quantity of processed fruit, with regard to the maximum quantity of processed citrus waste (i.e. about 280 millions of kg) the share of fibre is very close to the share of cloud (i.e. the difference between these productions is 0.29 % instead of the 1% of the first production interval). Table 5 also reports the relative price for fibre and cloud. Considering an average processing quantity of fruit about 70 millions of kg, the price for fibre and cloud results in accord with the Full Costs analysis for NAMASTE scenario A (i.e. 6.97 Euro/kg for fibre and 3.89 Euro/kg for cloud), because the inverse demand function, which determines the prices, was estimated on the basis of the marginal productivity and the production yield of NAMASTE computed in scenario A.

Fig. 3 Revenue and Cost, Marginal Revenue and Marginal Cost in Profit Maximizing, output for Fibre and Cloud production



Source: own elaboration

More in detail, in Fig.3 are reported the total revenue, cost and the marginal revenue and cost functions for fibre and cloud. Panel a. of Fig. 3 shows the trend for the fibre, of the total revenue (R_f) and the total cost (C_f) and the trend for the cloud for revenue (R_Cl) and cost (C_Cl).

The charts shows the convenience for the processor to exploit the production of citrus waste up to the point where the contribution margin of fibre and cloud is maximum. Producing up to this point, for the firm means to reduce the production cost and gain a competitive selling price (i.e. 1.98 Euro/kg for fibre and 2.27 Euro/kg for cloud). More in detail, the graphs in Panel a. show that the distance between revenue and total cost for both by-products (i.e. the segments ab and cd) achieves a maximum value when the marginal revenue of the fiber (see Panel b.) is equal to the respective marginal cost (MR_f = MC_f in Panel b.) and the MR_C falls below the RM_f. However, when the firm reached this maximum level, is no longer convenient to produce additional units of by-products. This is because that the production of an additional unit of the citrus fibre it would produce a loss, due to the MR_f <MC_f, going to reduce the overall profit. Moreover, pushing the production beyond this level would cause a decrease in the contribution margin of the cloud further reducing the amount of overall profit.

5. DISCUSSION

This paper examining the use of the Full Cost Method for planning and pricing decision in the Mediterranean citrus sector, providing a simulation model to use the full cost information to evaluate the profitability of innovative citrus by-products. The firms spend considerable resources on refining full-costing procedures with the aim to guide the decision making by give information and directions to the management. The results confirm the thesis of Balakrishnan et all. 2012 and Balakrishnan and Sivaramakrishnan 2002 where the Full Cost Method can be applied as a useful basis for simple and implementable decision rules in planning.

The model shows that the economic sustainability can be reached for both by-products depending on production scenario and by-product mix. The upgrade of vegetable residues (i.e. citrus waste) can create new capacity resources for citrus firm and improve the profitability of citrus production.

However just a small percentage of this material it is exploited by the NAMASTE technologies in order to obtain the by-products. The overall efficiency of the processing technologies is still quite low, representing a critical aspect that need to be improved in future research. Any possible improvement in the processing capacity of waste, could contribute significantly to the economic sustainability of such productions (e.g. an improvement of the 10 percent in the processing efficiency, can contribute to a reduction in processing costs and to an increase in profit margins).

With regard to the results of the full cost analysis (first part) the scenario A seems to be the most affordable one, the price was approximately 6.90 EUR, whilst the market price for dry fibre is 6 EUR/kg. Considering the approximations required to undertake the computation, the gap between the market price and the identified price for the Namaste product can be reduced either by modifying the hypotheses used or by improving the production process (i.e. ethanol consumption). The results for the cloud agent are economically sustainable referring to a market price which ranges from 1 EUR/kg to 4.78 EUR/kg.

Moreover, the hypothesis C is also potentially affordable, considering the production yield as a basis to calculate common costs (i.e. 3.51 EUR/Kg). The reference for the paste, as mentioned above, was 1.85

EUR/280 g. Based the information obtained from the Namaste research team, a hypothetical packaged product contains approximately 84 g of paste (in a product weighing 280 g, not including packaging). Outside the product costs related to promotion, transportation, mark-up etc., the approximate cost of the actual reference product becomes 1 EUR (or slightly less). Accordingly, the paste must not cost more than 0.30 EUR as it must substitute around one third of the reference product. The results referred to in Table 3 and Table 4 demonstrate that for hypotheses B and C the cost for the paste is only slightly higher than the cost of the similar ingredient in the reference product (i.e. it range from 0.35 EUR to 0.38 EUR/280 g). For hypothesis D, the cost is between 0.23 EUR and 0.25 EUR/280 g and is hence a more sustainable solution for the product in question. In light of the market prices, the economic sustainability of the processes is attainable in the production hypotheses A, C and F.

The modelling choice used in this paper, while reflecting a number of plausible assumptions also remains rather simplified and could be improved in the further research. The main weakness of the approach rests in the fact that the FCM requires a significant amount of information, often very detailed, about the technologies used, the quantities processed and the resources capacity. The management of this information is a critical point for the firms and for the effective use of this method, for the value of the information it can provide for the entire decision-making process. Hence, in this paper we used several hypothesis to scale up some laboratory results to an industrial level. This assumptions remain an approximation that can be improved in future research. One option for the future is the possibility of reducing production costs for fibre through the reduction in the use of ethanol and an improvement in the distillation process. It is also worth considering possible revenues from the sale of polyphenol extracts obtained during the processes, the price of which for feed in the market is quite high, approximately 23 €/kg.

The model can be improved on several other grounds, particularly focusing on managing the multi-period decision making instead of the one period setting that has been used for this paper, or considering the opportunity cost associated with installed resource capacity. Future research can focus on other costing system as the activity based costing, the resource consumption accounting or the Time-Driven Activity-Based Costing.

6. CONCLUDING REMARKS

This paper focused on the use of Full cost information within mathematical programming methods to test the economic feasibility of upgrading citrus waste in order to obtain novel type of by-products for multifunctional food ingredients in fruit juice and bakery goods.

Based on a product-mix model to solve the capacity planning problem and pricing decision of a Mediterranean citrus processor, the paper highlights the relevance of accounting cost allocations in optimisation tools searching for maximum profit and optimal product mix level. Although the economic sustainability of the analysed by-products is relatively achievable, it should be stressed that further improvements are possible in the efficiency of the developed technologies and protocols (i.e. improving the processing overall efficiency). Together with this technological improvements, also additional assumptions (i.e. re-use of the ethanol) and enhancements in the computation process (i.e. improving the scale up design and considering other costing system as the activity based costing) could refine the overall results. Such improvements would require a consistent development of implementation data collection, data analysis and process design and evaluation.

The discussion also demonstrated the weaknesses of this approach in the current form. Despite its limitations, due mainly to issues of data availability, the analysis showed the potential of the FCM for contributing to decomposing firm complex planning and pricing problem into simpler production problems. Future research could seek to analyse the implication of improve the design of cost pools and the selection of allocation bases on the quality of decision making.

Accordingly, the use of full cost method information with simulation model can improve the quality and the potential for managerial decision to address the planning and pricing of innovative by-products in the citrus sector.

ACKNOWLEDGMENTS

We acknowledge funding from the European Commission, 7th Framework Programme through the project NAMASTE (New Advances in the integrated Management of food processing wAste in India and Europe: use of Sustainable Technologies for the Exploitation of by-products into new foods and feeds). This work does not necessarily reflect the view of the European Union and in no way anticipates the Commission's future policy in this area.

REFERENCES

Balakrishnan, R. and Sivaramakrishnan K. (2002). A critical overview of the use of full-cost data for planning and pricing. *Journal of Management Accounting Research* 14: 2-31.

Balakrishnan, R., Labro, E. and Sivaramkrishank, K. (2012) Product costs as decision aids: An analysis of alternative approaches. *Accounting Horizons* 26(1):1-20.

Banker, R.D., and Hughes, J.S. (1994). Product costing and pricing. The Accounting Review 69(3) 479-494.

Bredenberg, K. (2004). An overview of trends in citrus oil production in the countries bordering the mediterranean, Paper presented at the IFEAT International Conference in Lisbon, Portugal, printed in the IFEAT Conference Proceedings, 58-76.

Cinquini, L. (2008). Strumenti per l'analisi dei costi, Vol.1, Fondamenti di cost accounting. In: (ed) Giappichelli, Torino.

Cohn, R., Cohn, A.L. (1997). Subproductos del procesado de las frutas. In: Arthey, D., Ashurst, P.R. (Ed.), Procesado de frutas, Acribia, Zaragoza, Spain, 288.

Cohen, S. C. and Loeb M. (1982). Public Goods, Common Inputs, and the Efficiency of Full Cost Allocations. *The Accounting Review* 57(2): 336-347.

Cooper, R., and R. Kaplan (1988) Measure cost right: Make the right decision. *Harvard Business Review* 96–103.

Datar, S.M., and Gupta, M (1994). Aggregation, specification and in product costing. *The Accounting Review* 69(4):567-591.

Dewan, R.M., and Magee, R.P. (1993). Product coting systems: Information, economics and implementation. Working Paper, Northwestern University.

FAOSTAT (2012) FAO statistical division. Available in http://faostat3.fao.org/faostat-gateway/go/to/home/E (Dec 19, 2012).

Fabio, F., Zanaroli, G., Vannini, L., Guerzoni, E., Bordoni, A., Viaggi, D., Robertson, J., Waldron, K., Bald, C., Esturo, A., Talens, C., Tueros, I., Cebrián, M., Sebok, A., Kuti, T., Broeze, J., Macias, M., Brendle, H.G., (2013). New advances in the integrated management of food processing by-products in Europe: sustainable exploitation of fruit and cereal processing by-products with the production of new food products (NAMASTE EU). *New Biotechnology* 30: 647 – 655.

Galati A. (2005). Libéralisation des échanges et compétitivité des pays méditerranées dans la filiére agrumes. Project de these Master, Institut Agronomique Méditerranées de Montpellier, France.

Govindarajan, V., and R. Anthony. (1983). How firms use cost data in price decisions. *Management Accounting* 65: 30–36.

Grohmann, K., Cameron, R.G., Buslig, B.S. (1995). Fractionation and pretreatment of orange peel by diluite acid hydrolysis. *Bioresource Technology* 54:129-141.

Gunaseelan, V.N. (2004) Biochemical methane potential of fruits and vegetable solid waste feedstock. *Biomass Bioenergy* 26:389-399.

Izquierdo, L., and Sendra, J.M. (2003). Citrus Fruit composition and characterization. In B. Caballero, L. Trugo, and P. Finglas (Ed.) Encyclopedia of food sciences and nutrition. Oxford Academic Press, 6000.

Laufenberg, G., Kunz, K., and Nystroem, M. (2003). Transformation of vegetable waste into value added products: (A) the upgrading concept; (B) pratical implementations. *Bioresource Technology* 87:167-198.

Lacirignola C., D'Onghia A.M. (2009) The Mediterranean citriculture: productions and perspectives. In : D'Onghia A.M. (ed.), Djelouah K. (ed.), Roistacher C.N. (ed.). *Citrus tristeza virus and Toxoptera citricidus: a serious threat to the Mediterranean citrus industry*. Bari : CIHEAM, 13-17. (Options Méditerranéennes : Série B. Etudes et Recherches; n. 65).

Mamma, D., Kourtoglou, E., Christakopoulos, P. (2008) Fungal multienzyme production on industrial by-products of the citrus-processing industry. Bioresource Technology 99:2373-2383.

Marìn, F.R., Rivas, C.S., Garcìa, O.B., Castillo, J., Pérez-Alvarez, J.A. (2005). By-products from different citrus processes as a source of customized functional fibres. *Food Chemestry* 100:736-741.

Martin, A.M. (ed.) (1998). *Bioconversion of waste materials to industrial products*. Second ed. Blackie Academic and Professional, London.

Miller, B.L., and Buckman, A.G. (1987). Cost Allocation and Opportunity Costs. *Management Science* 33(5): 626-639.

Mizuki, E., Akao, T., Saruwatari, T. (1990). Inhibitory effects of citrus unshu peel on anaerobic-dogestion. *Biol.Wastes* 33:161-168.

Pourbafrani, M., Forgàcs, G., Horvàth, I.S., Niklasson, C., Taherzadeh, M.J. (2010). Production of biofuels, limonene and pectin from citrus wastes. *Bioresource Technology* 101: 4246-4250.

Schimmenti, E., Borsellino, V., Galati, A. (2013) Growth of citrus production among the Euro-Mediterranean countries: political implications and empirical findings. *Spanish Journal of Agricultural research* 11(3):561-577.

Shim, E., and Sudit E. (1995). How manufacturers price products. *Management Accounting* 76 (8): 37–39.

Streenath, H.K., Crandall, P.G., Baker, R.A. (1995). Utilization of citrus by-products and wastes as beverages clouding agents. *Journal Of Fermentation And Bioengineering* 80(2):190-194.

Stewart, D.S., Widmer, W.W., Grohmann, K., Wilkins, M.R. (2005). Ethanol Production from citrus processing Waste, US Patent Application 11/052,620.

Vitali, P.M. (2009). Strumenti per l’analisi dei costi, Vol.3, Percorsi di Management. In (ed.) Giappichelli. Torino.

Widmer, W., Montanari, A.M. (1995). Citrus waste streams as a source of phytochemicals. In: 107th of the Florida State Horticoltural Society, Orlando/Florida, USA, vol. 107:284-288.

Wilkins, M.R., Widmer, W.W., Grohmann, K., Cameron, R.G. (2007). Hydrolisis of grapefruit peel waste with cellulose and pectinase enzymes. *Bioresource Technology* 98: 1596-1601.