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The Integrated Management of Food Processing Waste: The Use of the Full Cost Method for Planning and Pricing Mediterranean Citrus By-Products

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Abstract

This paper provides a methodology for the computation of the full cost of several citrus by-products and attempts to analyze, through a simulation model, the decision making process of a citrus firm seeking to upgrade citrus waste (CW) to several by-products. The results show the importance of using the full cost in the management of resources. Economic sustainability can be achieved by an increase in production efficiency, improving existing technologies and the ability to reuse waste. Yet a large amount of investment is still required, which only large firms can support, at least in the short-term.

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

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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 (FAOSTAT 2010). Moreover, in the Mediterranean basin, the three most important varieties of citrus, from an economic perspective (oranges, mandarins, and lemons), are prevalent, constituting a valuable reservoir of genetic resources for breeding and commercial purposes (Lacirignola and D'Onghia 2009).

Despite their importance, in recent 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 (Bredenberg 2004, Baldi 2011).

On one hand this loss can be attributed primarily to the increase in labor costs (Bredenberg 2004) in traditional producer countries (i.e. Spain, Italy, USA), along with the progress of emerging countries (i.e. China, India, Mexico, Brazil) characterised, on the contrary, by low-cost workforces. Low labor cost sourcing is a necessary condition to maintain a competitive advantage in the fresh products market. This is arguably the most important factor considering that citrus fruits, mainly oranges and small citrus fruits (tangerines, clementines, and mandarins), are in most cases handpicked.

On the other hand, there has been a change in consumer trends, particularly in the increased focus on quality and value-added products, but the required continuous investments in technology, production capacity, and high standards are lacking in most cases. Moreover, changes in lifestyle and especially in consumption (e.g. increased nutritional standards in developed countries, the expansion in world trade of high-value food products, and the evolution of consumer preferences toward smaller, easy-peeler and seedless fruits) have led to a change in the targets of fruit and vegetable producers, and in particular citrus producers. According to a United States Department of Agriculture (USDA) report on the world citrus market and trade (2014) the major citrus producing countries use most of their citrus production for processed products, resulting in a in a reduction in the availability of citrus on the fresh fruit market, which was previously the natural outlet for traditional producers. In Florida, despite a decline in production, 95 percent of oranges are still used for the preparation of juice. In Brazil, one of the world's largest citrus producers, two-thirds of orange production is used for processing. Together Florida and Brazil account for 90 percent of the orange juice produced in the world. In China, where the domestic market for orange juice is growing, more fruit is used for processing and in the European Union (EU), where fresh orange consumption is declining, increased processing can be expected in coming years (USDA 2014).

Changes in production have been taking place alongside the development of numerous technological advances in processing, storage and packaging. These improvements have allowed for an increase in the range of citrus produced, product convenience, and the healthfulness and quality of citrus fruit juices. Moreover, these changes have contributed to a rise in production costs and often a decrease in the availability of raw materials (Laufenberg et al. 2003).

The scarcity of raw materials, as a result of the above-mentioned increases in processing, has resulted in a significant recourse to imports, contributing to increases in processing costs and decreased advantages compared to rival countries where fresh product is more plentiful. In the globalized 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.

Mediterranean citrus companies need to sell all of the products and by-products obtainable from the fruit at a competitive price to assure their continued activity as citrus producers and processors (Bredenberg 2004). Accordingly, they must focus on recovering, recycling and upgrading by-products to obtain higher value and useful products (Laufenberg et al. 2003). This can also contribute to the reduction and indeed prevention of the pollution caused by the generation of large volumes of waste, both solids, and liquids, produced by the citrus processing industries.

There has been a noteworthy increase in the number of studies and research in the field of food and by-product recovery (i.e. see following section). The European Commission-funded 7th Framework 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, Joint European Commission & Department of Biotechnology (DBT)-India call: KBBE-2009-2-7-02: Valorisation of by-products in food processing) was directly focused on 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 were assayed and a final single multipurpose process providing alternative routes was implemented through the research activities. The peel, pulp and other citrus waste used for the production of the project by-products were obtained from European fruit juice companies acting as industrial partners in the project. Accordingly, the CW in question was not derived from either packinghouse eliminations or directly from groves, but rather from fruit juice processing waste.

The innovative character of NAMASTE lies in three protocols developed to obtain citrus by-products, namely citrus fiber, and polyphenolic extract, high pressure homogenization (HPH) paste and clouding agent, from citrus peel, pulp, segment membranes (citrus waste) obtained from the project’s industrial partners. The project, and our research, focused on these three by-products alone that were selected according to the NAMASTE project selection criteria, namely: exploitability for the market; the possibility to obtain a sufficient quantity of products to perform consumer tests; and food-grade certification of the processing equipment to perform consumer tests with the products produced. Furthermore, considering the seasonality of the processing and the limited time available for the project partners to perform extractions, studies, and consumer tests within the NAMASTE timeframe, only the above-referenced products were selected.

If these new technologies are considered from the perspective of a citrus firm, the choice to invest or not in the recovery of waste to obtain high value products calls for an economic evaluation of the full cost of the by-products in question. In performing this evaluation, the amount of waste produced can be considered as an additional capacity resource, where the costs of its management and uses must be accounted for to derive the profitability of the new products. Thus, the full costing facilitates the planning capacity and pricing decision process (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 seeks to bio-convert citrus waste into the above-mentioned by-products. The model is a mathematical programming model that integrates full cost data of citrus by-products (citrus fiber and clouding agent), maximizing the firm's 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 the potential for the management of medium-sized food processing companies. As there is no application of the full cost method (FCM) in the literature regarding the upgrade of vegetable residues for the production of multifunctional food ingredients in fruit juice and bakery goods, the paper constitutes a primer for future research aimed at developing an assessment of the economic sustainability of such innovative technologies.

The remainder of the study is organized as follows. The next section provides the background literature on citrus by-product recovery processing. 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.

Challenges Faced by the Citrus Industry

Of the vast amount of worldwide citrus production, only one-third is processed (Marín et al. 2005). The fruits processed are mainly oranges, followed by lemons and grapefruits. The principal target of the food industry is juice, but other products include: marmalade, mandarin segments, and flavonoids and essential oils produced respectively by the canning and chemical industries (Izquierdo and Sendra 2003).

As related by Cohn and Cohn (1997) and Braddock (1999), the amount of residue obtained from the fruits accounts for half of the whole fruit mass. Consequently, the food industry produces large volumes of solid and liquid wastes. According to Laufenberg et al. (2003), Mamma et al. (2008) CW have historically been dried and used as raw materials for pectin extraction or used without treatment for the production of animal feed or fertilizers. In recent years, however, the increasing costs associated with the storage and transportation of CW and the lower prices obtained from feed markets have resulted in the declining interest on the part of industry for these uses. At the same time, the necessity to prevent environmental pollution, and the need to conserve energy and raw-materials, has grown and new methods and policies for waste recovery and bioconversion for more useful, high-value, products are being introduced (Martin 1998, Laufenberg et al. 2003). Numerous multifunctional ingredients are being developed from citrus by-products and CW, notably: peel oil, oil and water-phase essences, pulp sacs, and Limonene.

Creating a secondary use for CW through the upgrading of citrus by-products can be considered a strategic element in the reduction of waste and the optimization of the use of existing resources.

Accordingly, the manufacturing industry must consider the potential economic and ecological benefits of green production methods (Laufenberg et al. 2003). The objective must be strategic management to increase product quality and safety, efficiency, and environmental aspects through the development of bio-innovations. Yet strategic management of this kind is not without challenges. This objective could be met by different approaches, which vary from the optimization of production processes to closed-loop production designs and the bio-conversion of CW into high-value products for the energy, food and bio-chemical industries.

Several research groups have been working on the development of multifunctional ingredients from citrus by-products and CW. Laufenberg et al. (2003) provide a list of innovative products obtainable from the upgrade of CW. These products include: dietary fibers, which constitute an excellent source of flavors, dyes and antioxidants, or as ingredients for the beverage and bread industries, as well as bioadsorbents, pectin, phytochemicals, gelling and stabilizer agents (Henn and Kunz 1996). Streenath et al. (1995) analyze the utilization of citrus by-products as a clouding agent, to influence the texture (enriching or adjusting the cloudy appearance) and viscosity of beverages. The organoleptic and chemical properties of CW offer a myriad uses for healthy and functional drinks and selected fruit juices (Laufenberg et al. 2003). Furthermore, CW could be used through enzymatic, cellulolytic, or 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), CW containing different carbohydrate polymers can be used for the production of biogas and ethanol. With a research target mainly focused on the exploitability for beverages, food and feed industries, evaluating the real possibilities of bringing research products to the market, the NAMASTE-EU project can be placed in this broad, and growing, body of literature. Hence, the by-products and protocols resulting from the project were analyzed through an environmental and economic assessment, providing an evaluation of the industrial relevance (Fava et al. 2013).

Methodology

The FCM was selected from management accounting theory for the computation of citrus by-product production costs. The FCM is based on the allocation of the costs of shared capacity resources to cost objects such as products (Balakrishnan et al. 2012). The full cost configurations obtained through the application of this costing system made it possible to achieve theoretically optimal product mix decisions using decision rules that simplify the capacity-planning and product-pricing problems. Dewan and Magee (1993) argue that the value of accounting allocations lie in the ability to deconstruct complex problems through simple decision rules that can be informationally demanding for small firms.

In this paper, the role of cost allocation in influencing managerial decisions of a citrus processing firm is examined through a simple one-period model of a firm that bio-converts product waste into new by-products. This approach takes its cue from the comprehensive literature review provided by Balakrishnan and Sivaramakrishnan (2002), yet stands apart by introducing the possibility of reusing a part of the utilized production capacity as “wastes to produce new products”. The allocation process is explained in the first part of the methodology while the model is introduced in the second part.

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 plus the allocated capacity resource costs. According to economic theory, the full cost may not be the right metric for addressing short-term planning problems due to the uncontrollability.

Yet, despite the considerable criticism and its recognized limitations, the FCM is nonetheless still widely used in 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 to valuate inventories and calculate income, for product and resource planning and to help managers induce desired organizational behavior. Furthermore, Govindarajan and Anthony (1983), Shim and Sudit (1995) and Cooper and Kaplan (1998) have demonstrated that firms do, in fact, allocate an amount of fixed overhead to obtain a product’s full cost to make a comparison between different product alternatives.

The FCM is based on the principle of full cost absorption (Cinquini 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 incurred by the firm). This principle involves the problem of the allocation of common and special costs, which are not directly imputable to the products, and thus the identification of a suitable basis for the allocation.

The special costs are those consisting of the value of the factors whose services are used only 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 factors effectively consumed by the object multiplied by the unit price. However, common costs are those factor costs that are used simultaneously by multiple objects of cost for which it is difficult to distinguish the specific quantity of consumed factors. They should be allocated to the object of cost by way of an allocation procedure (Cinquini 2008).

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 products. In other words, with the FCM it is possible to calculate the cost of each product from the indirect production costs, which are usually generated from different processes using the same equipment (Cinquini 2008, Vitali 2009).

A product cost configuration, according to Cinquini (2008) highlights four cost types related to different cost pools (Figure 1). The first cost includes raw materials, the direct costs of external processing, direct labor and direct production costs (operating costs). The production cost includes (in the first cost) a share of indirect production costs that, together with the general commercial and administrative expenses, represent the full company cost.

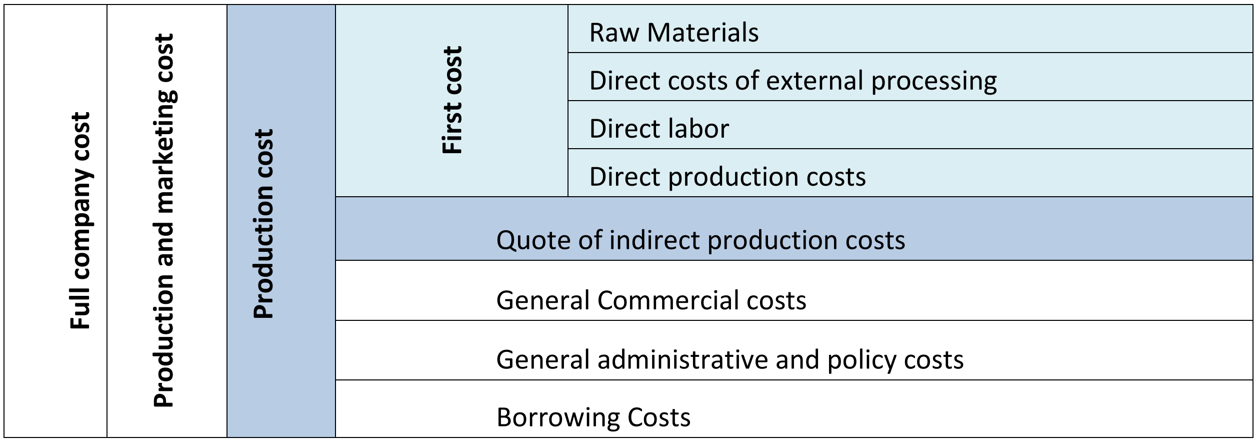

Figure 1. Product cost configuration
Source. Cinquini 2008

The calculation of a product's full cost differs significantly from one firm to the next, depending on the sector of activity (manufacturing, commercial, service provision etc.) and the type of production process. These factors can affect the identification of the cost pool, which is necessary for the cost allocation, in particular for the distinction between the direct costs and overhead costs that should be allocated according to cost driver units (machine hours, € /labor hours, etc.).

According to Cinquini (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 basis FCM, the economic literature provides the follow processing steps:

1. Choice of the indirect cost elements (capacity costs, overhead, production and structure) to aggregate in cost pools, according to cost aggregation criteria;
2. Choice of the cost driver units (labor hours, machine hours, € /labor hours, etc.). This phase is the most important, and also the most criticized[1] (Balakrishnan et al. 2012). In this phase the proportionality of the volume of indirect costs is determined with respect to the allocated cost object, 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. The determination of 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.

Applying the notation developed in Balakrishnan et al. (2012), a formalized structure of the allocation system within the FCM is provided in the following scenario. Consider a firm that supplies an amount of capacity resources J (labor hours, tons of raw materials, machinery hours, etc.) at some cost per unit of capacity. K are the cost objects (i.e. the costs associated with the

[1]The main criticality is closely linked with the correct choice of such allocation basis. Cinquini (2008), distinguishes between value basis (expressed in monetary terms) and quantitative basis (e.g. labor hours, machine hours, quantity of raw material, etc.). The choice of the correct basis should follow the functional criterion (e.g. the causal principle).

products developed) 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 by 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} defines the number of cost driver units (e.g. labor hours) that connect the consumption of cost pool l to 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 costs 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 products developed).

Let $\varphi_{lk}=\frac{CP_l}{\sum_k CD_{lk}}$, with $\varphi_{lk}>0$ represent the allocation coefficients that are obtained as the ratio of the 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. An estimation of this kind 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 and the scope of the process determining the optimal quantities, a sensitivity analysis was carried out on the amounts of processed waste to take into account the possibilities and constraints for adaptation by the firm. Assuming that the firm's objective is the maximization of profits, a one-period mathematical programming model was developed to assess the optimal product-mix levels.

The model considers a citrus juice processor that produces by-products from CW (e.g. citrus fibers, clouding agent etc.). The firm's ability to use waste to produce by-products corresponds to an increase in production capacity. Following the theoretical approach of Balakrishnan et al. (2012) the processor is a "price taker" with fixed capacity in the production of the principal goods, while at the same time, the by-product market is relatively new, and the firm is monopolistic in this market. This assumption accounts for the firm's ability to influence demand by adjusting prices based on its marginal productivity. The firm has full information on the by-product market and can estimate potential market demand. Accordingly, the firm sells what it produces (without stocking product) and set the price to minimize opportunity costs (costs associated with the use of citrus waste for by-product production).

Furthermore, the ability to use wastes to produce by-products is considered to be 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 is recovered and reused for the production of citrus fiber and clouding 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 $S_{ji} = (1 - \alpha)T$ representing the additional resource capacity acquired from the reuse of wastes. However, the firm must pay a cost to exploit wastes, represented as θ_j>0 for all j. Let x_i be the amount of by-products produced.

Let $x_i=(A_i - w_i)/B_i$ be the linear demand function for the production of by-products, where $A_i, B_i > 0$ states 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 the production of the by-products. $w_i = (A_i - B_i x_i) \geq 0$ represents the inverse demand function determined the by-product price.
As a result, the model takes the following structure, given the fixed value of production capacity resources (T) and by maximizing the gross margin (GM):

Max

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

Subject to:

(2) $x_i \leq \sum_j^J m_{ji} S_i \quad \forall i,$

(3) $w_i, P_i, x_i \geq 0 \quad \forall i.$

Where:

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

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; a simulation exercise for two NAMASTE by-products was run using the results of the analysis. The model was built in GAMS, and simulates the planning and pricing problem of a citrus juice firm that seeks to recover and bio-convert citrus waste to produce citrus fibers and clouding agents.

The full cost analysis of the NAMASTE by-products was focused on citrus fiber and polyphenolic extract, a high-pressure homogenization (HPH) paste and clouding agent. The innovative nature of the NAMASTE by-products lies in the protocols developed, even though some (e.g. citrus fiber and clouding agent) have been widely produced by the processing industries. Dietary fiber represents the indigestible polysaccharides and oligosaccharides found in fruit, vegetables, grain, and nuts. The citrus fibers can be used as matrices for flavors, dyes or antioxidants (Laufeberg et al. 2003). The soluble and insoluble dietary fibers have beneficial effects on human health and can be developed for use in bread or beverages. Furthermore, the peel cloud, also known as clouding agents (CA), 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 compare with existing products on the market. On one hand, since the NAMASTE project was a research project, all of the relevant information and data from the protocols were acquired from laboratory results (i.e. quantity of processed by-products, raw materials, processing time and waste produced). On the other hand, several assumptions were made to scale up the products to an industrial level. For the scaling up process it is necessary to first estimate the production objectives for the three processes being analyzed, making it possible in turn to identify the size of the hypothetical processing pilot plant in terms of the amount of by-product to be processed (in tons/year). Then we made several assumptions about the required amount of labor, raw material consumption, the duration of the production processes and the machinery required for the processes. Furthermore, an exhaustive interview was carried out with the NAMASTE industrial consortium members to seek clarification and to obtain an accurate basis upon which to calculate the processing costs. Data about the annual production of the plant, the number of employees, processing time, processing phases, and equipment model numbers and brand names etc. were sought for the calculation process. In addition, while all of the relevant and available cost information was acquired from the partners, it should be noted that the collection of comprehensive data can be difficult to obtain given that industrial partners need to respect internal policies regarding the privacy of industrial data.

On the basis of the information acquired, a model of a citrus processing plant exploiting the three NAMASTE protocols was developed. It was assumed that annual citrus by-product volumes were approximately 72,000 tons, to be allocated as an input into several alternative product mix hypotheses, enumerated below: a) 50% Fiber/50% Cloud; b) 50% fiber/50% Paste; c) 50% Cloud/50% Paste; d) 100% fiber; e) 100% Cloud; and f) 100% HPH Paste. The first three production hypotheses represent a combined production alternative in which only two processes are analyzed at a time. The other points involve the production of only one product at a time. Furthermore, production hypothesis A considers that a fiber fraction can also be obtained as a by-product during the production of clouding agent. In the production of approximately 36,000 tons of by-product for the manufacture of the clouding agent, about 19% (6,808 tones) were re-used for the production of fiber.

In keeping with the information provided by the NAMASTE industrial partners, a continuous production process was assumed to operate 8 hours/day, 253 days/year, hence allowing for a distribution of the workload over the year. In reality, however, the citrus industry operates seasonally. Citrus products are generally processed over a 4-6 month period and during the rest of the year the plant activities are focused on either the loading or unloading of raw materials or equipment maintenance. The assumption mirrors reality whilst simplifying the cost computation as it allows for the inclusion of the production costs involved in the equipment maintenance periods and the cost of loading and unloading raw materials. Furthermore, the citrus plant employs 6 full-time workers, as follows: three technicians (€30,000 /yr.), two warehouse workers (€30,000 /yr), and one marketing staff (€58,000 /yr.). Moreover, a payback period of six years is assumed to recoup initial investments.

Once the problem was defined, the full cost analysis was carried out 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; and e) Calculation of the full unitary costs (citrus fiber, clouding agent and HPH citrus paste).

The computational steps required for the allocation of capacity costs are provided for the production process (Table 1). Furthermore, to simply the exposition, the computation of variable overhead costs has been ignored as these costs can be assigned to cost objects with relative ease.

Table 1. FCM, firm data input

Panel A: Data on Costs (€)			
Total factory overhead	2,701,229		
Total general overhead	265,000		
Total overhead	2,966,229		
Panel B: Data on Volume and Labor consumption (Cost driver unit)			
	Fiber	Cloud	Total
DLH	7,084	5,060	12,144
(Staff unit per Labor consumption hours per work day)			
Yield production (t/year)	3,142	2,340	5,482
Panel C: Allocation of Cost Based on Direct Labor Hours			
Overhead rate= €2,966,229/12,144= €244.25 per labor 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 t (rounded)			
	Fiber	Cloud	Total
Total cost to product	1,700,233	1,265,996	2,966,229

Source. Authors' own elaboration

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

The results of the full cost analysis of the NAMASTE processes for hypotheses A, B, C are provided (Table 2). The full cost per unit (€/kg) is reported as a ratio of 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 obtain each final product.

Table 2. Results of NAMASTE processes A, B, and C

Product Mix	**Allocation criteria**	**fiber unitary cost (€ /kg)**	**Cloud unitary cost (€ /kg)**	**HPH unitary cost (€ /kg)**
A. 50 % Fiber/ 50 % Cloud	Direct labor hours	6.88	4.01	
	Yield Production	6.87	4.02	
B. 50 % Fiber/ 50 % Paste	Direct labor hours	7.07		4.27
	Yield Production	6.36		4.28
C. 50 % Cloud/ 50 % Paste	Direct labor hours		4.15	4.27
	Yield Production		3.51	4.28

Source. Author's own elaboration

There were no significant differences in the three cases analyzed that would justify the choice of an allocation policy based on volume rather than on the amount of labor consumed. The cost for the dietary fiber and the clouding agent can be compared with the reference market prices of €6 /kg for fiber and a range of €1 /kg to €4.785 /kg for clouding agents (data provided by the NAMASTE industrial partners). In process B, the price of the fiber is closer to the market price when using as allocation criteria the volume of the processed by-product. In process C, with regard to the second allocation option, the full unitary cost of clouding agent is still lower and largely within the market range. The reference price for the HPH paste was €1.85 /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). Not taking into account the costs related to promotion, transportation, mark-up etc., the approximate cost of the actual reference product is €1 (or slightly less). Accordingly, the paste must not cost more than €0.30 /84 g, as it would account for around one-third of the reference product. The results show that for processes B and C the cost of the paste is only slightly higher than the cost of the similar ingredient in the reference product (i.e. varying slightly from €0.35 to €0.38 /280 g).

The results of processes D, E, F, considering separately the production of Fiber, Clouding agent and HPH paste are provided in Table 3.

Table 3. Results of NAMASTE processes D, E, F (source: own elaboration)

By-product	Fiber unitary cost (€ /kg)	Cloud unitary cost (€ /kg)	HPH unitary cost (€ /kg)
D (100% Fiber)	7.07		
E (100% Cloud)		4.13	
F (100% HPH Paste)			2.85

Under the alternative process D, according to our calculation, the NAMASTE price for fiber was quite high (€7.07 /kg) since the market price for dry fiber is €6 /kg. However, in 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, the mathematical programming model was applied using the results of process A. The one-period model hypotheses a citrus juice firm that seeks to exploit citrus waste (i.e. mainly pulp, membrane and peel) obtained from the extraction of citrus juice, to produce citrus fiber and clouding agent. In keeping with the literature, it was assumed that the total processed citrus fruit provides about 60 per cent of citrus juice, while the remaining 40 per cent represents the raw material to produce the new by-products.

The relevant information about by-product costs was taken from the full cost analysis in process A. The price for the citrus juice was fixed at €2 /lt, based on the average of current market prices that range from €1.74 /lt to €2.40 /lt for organic juices. It was assumed that the marginal revenue for the juice production is about €1.40 /lt of product, excluding the cost of packaging, marketing and transport. Assuming that the firm can process more than the 72,000 tons of CW produced in A, we chose to perform a broad sensitivity analysis on the total amount of processed citrus fruit (i.e. the total resource capacity) to evaluate different production strategies in terms of product mix, prices and costs.

Thus, the problem becomes a planning decision issue, regarding how much of the new capacity resources (e.g. CW) can be allocated between the various by-products. In other words, what is the optimal combination of by-products required to maximize the overall profit?

The results of the optimization are provided and it is assumed that the citrus firm maximizes the profit resulting from the production of the juice, fiber and clouding agent (Table 4 and Figure 2).

The gross margins for each process, the amount of fiber and clouding agent produced, as well as the relative costs and prices are reported. For the amount of processed fruit, a sensitivity analysis is carried out (millions of kilograms). Given that the firm is not producing citrus fiber and cloud, the first row provides the amount of fixed costs required to commence production. Furthermore, the share of fiber and cloud produced is growing, but at different ratios depending on the marginal costs. In addition, for each level of resources, the production of cloud is greater than the production of fiber. However, considering the sensitivity analysis conducted on the quantity of fruit processed, with regard to the maximum quantity of processed citrus waste (i.e. about 280 million kg) the share of fiber is very close to the share of cloud (i.e. the difference between these production levels is 0.29 %, whereas it was 1% in the first production interval). Taking an average fruit processing level of about 70 million kg, the price for fiber and cloud is in keeping with the full costs analysis for NAMASTE process A (i.e. €6.97 /kg for fiber and €3.89 /kg for cloud).

Table 4. Results of NAMASTE model for scenario A

Processed citrus fruit (millions kg)	Gross Margin (millions €)	Fiber production (millions kg)	% Fiber/ CW	Fiber price (€ /kg)	Cloud production (millions kg)	% Cloud/ CW	Cloud price (€ /kg)
0	-1.7	0	0	0	0	0	0
10	9.1	0.4	4.52	7.45	0.5	5.98	4.12
30	30.0	1.2	4.13	7.29	1.8	6.28	4.04
70	71.2	2.8	4.05	6.97	4.4	6.34	3.89
130	131.3	5.3	4.09	6.47	8.2	6.31	3.66
200	198.9	8.4	4.24	5.84	12.4	6.20	3.41
260	254.4	11.9	4.59	5.15	15.4	5.93	3.23
350	330.7	13.8	3.96	4.76	15.9	4.55	3.20
400	372.7	13.8	3.46	4.76	15.9	3.98	3.20
600	540.7	13.8	2.31	4.76	15.9	2.65	3.20
700	624.7	13.8	1.98	4.76	15.9	2.27	3.20

Source. Author's own elaboration

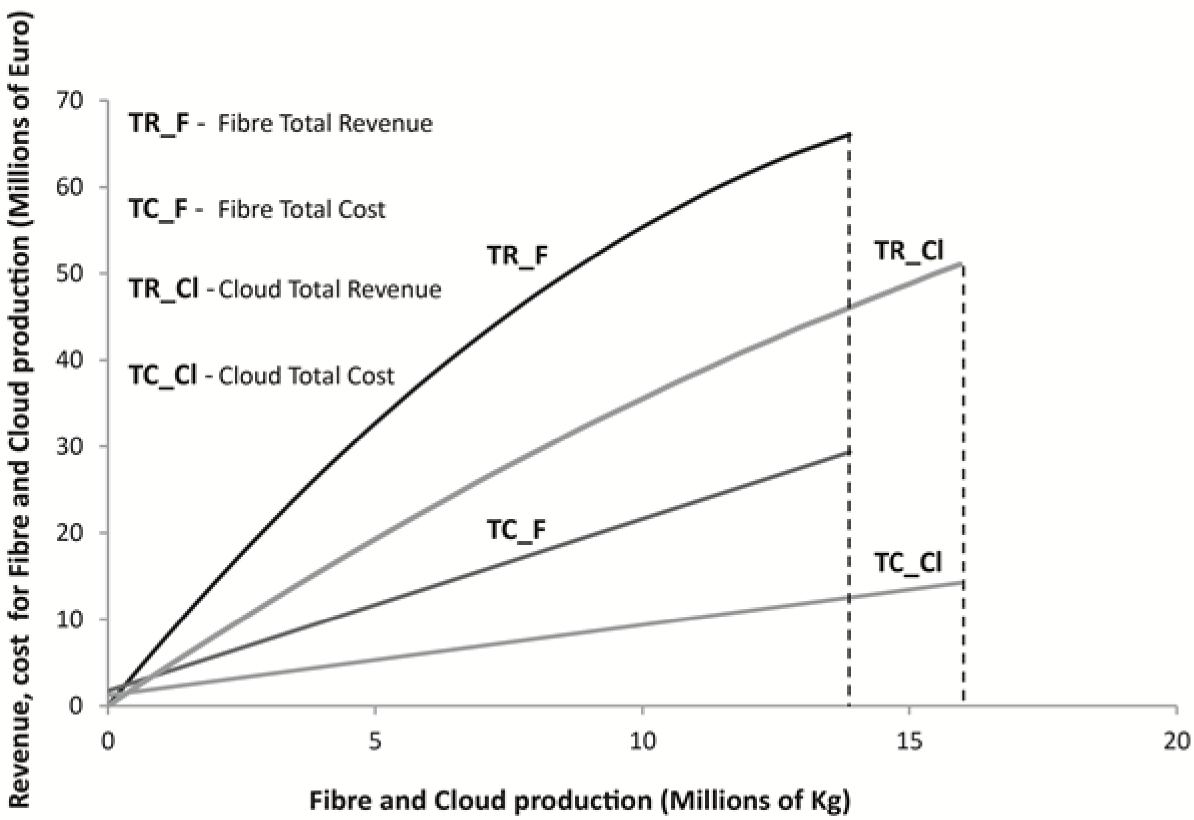

Figure 2. Total Revenue and Cost in Profit Maximizing and Output for Fiber and Clouding agent production

With a volume of 14 million kg, the production of fiber reaches maximum revenue of about €65 million, while for the same volume cloud generates around €45 million in revenue. Cloud reaches maximum revenue of around €50 million with a volume of around 16 million kg.

Discussion

This paper examines the use of the full cost method for planning and pricing decisions in the Mediterranean citrus sector, providing a simulation model for the use of full cost information in the evaluation of the profitability of innovative citrus by-products. Firms spend considerable resources on refining full-costing procedures to guide decision-making and to provide information and direction to management. The results confirm the thesis of Balakrishnan et al. (2012) and Balakrishnan and Sivaramakrishnan (2002) whereby the FCM can be applied as a useful basis for simple and implementable decision making rules in planning.

The full cost analysis (step one) and the simulation exercise (step two) were applied under several assumptions and six product mix hypotheses in order to evaluate the most economically affordable NAMASTE by-product combinations.

The main assumptions for this analysis involved the identification of the size of the hypothetical processing plant, the amount of by-product to be processed, the duration of the production processes and the machinery required for the processes. Based on the information provided by the NAMASTE industrial partners, it was assumed that a large plant would be required to process large quantities of CW over a period of 253 days/year. Changing the assumption with regard to the size of the processing plant would necessarily entail a different scale of production and hence impact on the profitability of the by-products. While changing the assumption of the length of the production cycle to reflect the seasonability of citrus juice processors would not have negative ramifications for by-product profitability. The by-product production cycle generally starts after the production of citrus juice (with the resulting CW) and can be reasonably extended during the off-season months including during the load/unload, production, and equipment maintenance phases. It is also assumed that the plant in question is that of a large, fully equipped company and does not require new significant investments in machinery to produce the by-products. Accordingly, it would not be profitable for a small company without such equipment as the investments required would be excessively onerous.

However, maintaining the main assumptions of this analysis, the overall picture shows that economic sustainability can be reached for the NAMASTE by-products regardless of the tested product combinations hypotheses.

With regard to the tested hypotheses, the results of the full cost analysis for hypothesis A, the production of half fiber and half cloud, seems to be the most affordable: the price for fiber was approximately €6.90, while the market price for dry fiber is €6 /kg. The results for the clouding agent are economically sustainable when compared to a market price that ranges from €1 /kg to €4.78 /kg. Hypothesis C is also potentially affordable, considering the production yield as a basis to calculate common costs (i.e. €3.51 /kg). Moreover, 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 ranges from €0.35 to €0.38 /280g). As for hypothesis D, the cost is between €0.23 and €0.25

/280g 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 production hypotheses A, C and F.

The results obtained in the simulation exercise (step 2) confirmed the feasibility of hypothesis A. Yet these results underscore the fact that the production of small volumes yields limited margins while, according to our assumption regarding the recovery of larger quantities of waste, it is confirmed that process A is more adapted to the production capabilities of larger industrial processing plants (i.e. the industrial partners in the NAMASTE project consortium). The NAMASTE project focused only on the analysis of full costs and not on the global investment required by companies electing to process citrus waste; this latter analysis is particularly pertinent for determining the overall feasibility and profitability of the analyzed by-products and constitutes an excellent avenue for future research.

The choice of the models used in this paper, while reflecting a number of plausible assumptions nonetheless remains somewhat simplified and could be improved upon in further research. The main weakness of the approach rests in the fact that the FCM requires a significant amount of often very detailed information about the technologies used, the quantities processed and the resource capacity. The management of this information is a critical point for the effective use of this method and for the value of the information it can provide. Hence, in this paper we used several assumptions to scale up laboratory results to an industrial level. These assumptions remain an approximation that can be improved upon in future research. The model can also be improved in other ways, such as through the use of multi-period decision making instead of the single period setting that was used in this paper, or considering the opportunity costs associated with the existing capacity resources. Future research could also focus on other costing systems, such as activity based costing, resource consumption accounting or Time-Driven Activity-Based Costing.

Conclusion

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

The paper uses a product-mix model to solve capacity-planning problems and to address the product-pricing decisions of a hypothetical Mediterranean citrus processor. Moreover, it highlights the relevance of accounting cost allocations through the use of optimization tools the purpose of which is to determine maximum profits and optimal product mix levels.

Although the economic sustainability of the analyzed by-products is achievable, it should be stressed that further improvements in the efficiency of the developed technologies and protocols (i.e. improving the overall processing efficiency) are possible. The technologies developed in the project focused on the development of innovative ingredients for the food and feed industries. The overall efficiency of the processing technologies is still quite low; moreover, the production of fiber and cloud can be optimized through future research aimed at improving the distillation process and reducing the use of ethanol. Considering that polyphenol extracts, with a price of approximately €23 /kg, can constitute an additional source of revenue for the processor, any improvements in the distillation phase can contribute to the lowering of production costs and an increase in the profitability of by-products.

Together with these technological improvements, additional assumptions (i.e. re-use of ethanol) and enhancements in the computation process (i.e. improving the scale up design and considering other costing systems for the activity based costing) could also refine and improve the overall results. Further development of the methods aimed at data collection, data analysis, process design and evaluation would be necessary to achieve such improvements.

The discussion demonstrated the various weaknesses of the approach in its current form. Despite the limitations (mainly related to data availability), the analysis demonstrated the potential of the FCM to contribute to breaking down the complex planning and price determination problems faced by firms into simpler production problems. Future research could analyze the implications of improving the design of cost pools and the bases of cost allocations for decision-making.

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

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