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Financial Sustainability and Profitability of Supercritical CO_2 Pasteurization of Liquid Products: a Case Study

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This work presents an analysis of a supercritical CO_2 (SC-CO_2) pasteurization process, focusing on the financial and economic parameters that make the process sustainable at an industrial level. A small company processing 5,000,000 bottles of apple juice per year has been chosen as a case study. Investment and operating costs have been estimated based on data collected from the market and the relevant economic literature. The financial sustainability assessment was performed through the Discounted Cash Flow methodology, proving that SC-CO_2 pasteurization is profitable on a 10-year horizon. The Net Present Value is strictly positive and the Internal Rate of Return higher than the cost of funding. The sensitivity analysis shows the robustness of this study to possible changes in the model parameters. Overall, this work demonstrates SC-CO_2 pasteurization to be profitable and, considering the current growth of the high-nutritional value fruit juice market, it suggests positive financial returns for both incumbents and new entrants.

1. Introduction

Pasteurization with supercritical CO_2 (SC-CO_2) has been studied for decades as an alternative low-temperature cold pasteurization technique. The process is effective to inactivate microorganisms and enzymes in solid and liquid products thus extending the shelf-life and the preservation of nutritional (Bertolini et al., 2020) and sensory characteristics (Marszałek et al., 2018). The inactivation efficiency can be increased by coupling High Power Ultrasounds (HPU), which enhance the mixing and the mass transfer and shortens the processing time (Paniagua-Martìnez et al., 2016).
Despite its proven efficiency at a pilot-scale (Fabroni et al., 2010), SC-CO_2 pasteurization for liquids is not commercially adopted. Commercialization has been attempted a few times but SC-CO_2 pasteurized products never reached market distribution (Spilimbergo, Matthews e Zambon 2018). Investment and operating costs have been claimed to be one of the barriers to the market (Shi, 2016) but no studies on the financial sustainability of the process have been run. A preliminary financial valuation is necessary to identify those parameters driving investment decision like the amount of funding needed, operating costs and potential returns for investors. Many market players could be prevented from investing in innovative technologies due to the lack of such relevant information (Hölzl e Janger, 2012).
The present work aims at estimating the cost of an industrial SC-CO_2 pasteurization plant and assessing the sustainability and profitability of this technology at an industrial scale during ordinary market conditions. To this end, a small company operating in the Italian high-nutritional fruit juice market has been analysed as a case study.

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2. Materials and Methods

2.1 Plant description

The considered pasteurizing plant has a 200 l/h capacity and it has been designed from the laboratory-scale equipment described by Gomez-Gomez et al. (Gomez-Gomez et al., 2020). The raw juice is initially stored at atmospheric pressure while the CO_2 is stored in a pressure tank. Both the juice and the CO_2 are separately pumped with high-pressure membrane pumps to the processing pressure between 10 and 15 MPa. The juice flow rate is 0.556 kg/s and CO_2 flow rates can be adjusted from 0.055 to 0.278 kg/s to obtain a mass-flow ratio between juice/CO_2 ranging from 2 to 10.
The two flows are heated up to the processing temperature (between 293K and 323K) in a heat exchanger and mixed in a vertical ultrasonic vessel considered as a perfectly mixed vessel. The inactivation effects are enhanced by maintaining the contact between the juice and the CO_2 in a tubular reactor placed in series with the ultrasonic (US) vessel. After treatment, the mixture is depressurized in a high-pressure control valve. A separator is used to separate the CO_2 from the juice. The juice is collected automatically at the bottom through an automated drain valve. The CO_2 is recycled to a condenser and stored again in liquid state in a low-temperature reservoir. The juice is then collected and stored in an atmospheric pressure refrigerated tank for about 30 minutes for degassing and it is then moved to the aseptic bottling machine.

2.2 Valuation methodology

The value of the investment and its profitability have been assessed by computing the Net Present Value (NPV) through the Discounted Cash Flows (DCF) methodology. The DCF is a valuation technique used to estimate the value of an investment based on the expected cash flows. The analysis aims at determining the present value of an investment by looking at the magnitude of the cumulative cash flows to be generated by the project in a fixed time horizon (Burr Williams, 1938). Considering the size of companies where the analysed plant is expected to be implemented, the Return To Equity (RTE) approach has been chosen. Indeed, the RTE approach is "applicable for smaller, non-corporate firms whose leverage fluctuates over time and that lack access to the national markets for debt and equity (and) is consistent with the smaller-scale, non-corporate structure of most farm businesses" (Barry and Ellinger, 2000). Different from the common Return To Asset (RTA) approach, this one emphasizes the firm's equity invested in the project. Observed cashflows are thus retrieved by subtracting interests paid on debt and loan principal reduction from the operating income as described in Eq. 1.

$$CF_t = (R_t - C_t - A_t - iL_{t-1})(1 - t) + A_t - (L_{t-1} - L_t) \quad (1)$$

Where CF_t is Cash flow, R_t is revenues, C_t is costs, A_t is the depreciation, L_t is the debt service, i is the interest rate and t is the tax rate.

The Net Present Value is then computed as

$$NPV = -INV_0 + \sum_{t=1}^{t=T} \frac{CF_t}{(1+r)^t} + \frac{TERM_T}{(1+r)^T} \quad (2)$$

Where INV_0 is the equity initially used to start the project and $TERM_T$ is the terminal value.

The Internal Rate of Return (IRR), the discount rate setting the NPV to zero in a DCF analysis, was computed together with the NPV. IRR calculations rely on the same formula as NPV does.

2.3 Data on economic and market conditions

The hypothesis underlying this work is that SC-CO_2 processed juice has the same quality as the one treated with the cold pasteurization technique currently available on the market. Thus, information on prices, consumers behavior and market characteristics obtained from the analysis of the cold pasteurized juices segment can be applied also to the SC-CO_2 processed juices. As a case study, an average Italian company, in the SME segment, operating in the high-nutritional value fruit juice market has been chosen. The company is assumed to sell only apple juice. The time frame of the analysis is 10 years as suggested by Peters and Timmerhaus (1991) for supercritical CO_2 pasteurization plants.
The setting up of the case study required interviewing a market operator. In 2018, the Italian market of cold-pressed fruit juices was worthing about 48,000,000 € with almost 25,000,000 bottles sold and it was showing a promising 3% yearly growth. Starting from these data, the study considers a plant processing 5,000,000 bottles at year 1 and a 3% growth rate is applied to both revenues and variable costs. These hypotheses are

consistent with the production volume of an average company in the Italian market but the expected growth has been spread over 10 years for prudency's sake.
The project is supposed to be funded with a mix of debt and equity, respectively 82.53% and 17.47% of the initial investment. The debt/equity rate follows what stated by Damodaran (2020) in his latest databases on European companies operating in the food processing industry. From the same database, the cost of debt (3.96%) and the cost of equity (6.18%) have been retrieved too. The Italian tax rate on corporate is 24% (i.e. IRES). The repaying debt scheme is of the French kind so the debt service is constant and the interests' quota is decreasing over time. The debt is supposed to be repaid in 10 years. Both on revenues and costs the yearly inflation rate is constant and equal to 2% according to European Central Bank's expectation for the Euro area (ECB, 1998).

2.4 Data on investment and operation costs and revenues

The initial investment is comprehensive of both the cost for the pasteurizing plant and the cost for an aseptic filler. The estimated expenditure for the plant is 600,000 € and it includes the unit with all the systems, initial kit of spare parts, the installation and commissioning, start-up and training, service & support and warranty. The cost of the aseptic filler considered in this paper is 1,550,000 € and this information has been collected by surveying three different suppliers. In fact, the filling machine under evaluation is ten times bigger than the one which should fit 5,000,000 bottles/year but, at the present day, no smaller aseptic filling machine can be found in the market.
Energy requirements are comprehensive of the total energy requirement needed for using the system, including electrical energy required for the high-pressure pumps, the US transducer and the chiller needed to condense the CO_2 in the recycling loop working at 5 MPa. It is also count of the fossil gas needed to supply hot water that is used to pre-heat the juice and the CO_2. Energy requirements are estimated globally at 28 kWh, of which 14 kWh for electricity and 14 kWh for the gas energy.
The cost of energy has been set by looking at public data on non-household consumers by Eurostat. Data are updated to the first semester of 2020 and the reported cost for electricity is 0.1503 €/kWh (Eurostat, 2020a) while the reported cost for gas is 0.308 €/kWh (Eurostat, 2020b) (for both electricity and gas prices, VAT and other recoverable taxes and levies are excluded).
According to the Italian Collective Labour Agreement for Agricultural workers, the cost of personnel comes from the collective labour agreement for type B workers in the agriculture industry. The hourly cost born by the firm is 17.52 € including taxes, contributions, and severance package.
The cost of juice is 1.86 €/l. This amount has been computed by summing up the cost of the fruit, 1.33 €/kg and the cost of pressing, 0.09 €/l. The cost of the fruit refers to the price stated for Cripps Pink apple on the 20th November 2020 in Bolzano Market (Ismea, 2020) while the cost of pressing has been estimated by interviewing market operators. On average, 1.4 kg of apples is required to get one litre of juice (Bates, Morris & Crandall, 2001).
As the CO_2 used in the process is mostly recycled, the estimated hourly CO_2 consumption is 10 kg on average. Bulk cryogenic CO_2 price is taken from the quotation of an industrial gas supplier in western Europe and it is 0.15 €/kg.
Cold-pressed juice is commonly sold at no less than 1.89 € per bottle in retails and the applicable VAT is equal to 10%. Both a surveyed supermarket chain and fruit juice company stated a 50% distributor margin on the final price. Based on this information, the juice is then supposed to be sold to the trade at 0.8505 € per bottle.
Operational overhead costs have been determined by exploiting the equation proposed by Turton et al. (1998):

$$COM = C_{RM} + C_{WT} + C_{UT} + 2.215C_{OL} + 0.19COM + 0.236FCI \quad (3)$$

COM is the total cost of manufacturing,
C_{RM} is the cost of the raw material needed to operate the process,
C_{WT} is the cost of waste management, which in our model is equal to zero as none of the technologies requires special procedures to manage the waste,
C_{UT} is the cost of the utilities,
C_{OL} is the cost of personnel,
FCI is the fixed capital investment.
Turton's equation is a good approximation to include the indirect costs of a chemical process such as administration, supervision, distribution, etc. Among the multiplying factors, there are ordinary annual maintenance and depreciation rate to be considered. They are respectively estimated as 5% and 10% of the initial investment.

Consistently with the depreciation rate, an expected life of 10 years has been assumed.

3. Results and Discussion

3.1 Revenues and Costs

For a 200 l/h plant pasteurizing 5 million bottles at year1, revenues and costs are:

- Revenues: 4,337,550 €
- Cost of Manufacturing: 3,995,130 €
- Cost of Third-Party Financing: 46,217 €
    - Interests: 14,874 €
    - Principal Repayment: 31,343 €

The main cost element of the raw material is untreated apple juice. In particular, untreated juice counts for 99.53% of the cost for raw material, while the remaining is CO_2. As the cost of untreated juice is common to every kind of pasteurization, the net cost for the raw material of SC-CO_2 is low. Not considering the cost of untreated juice and overhead costs, the cost of pasteurizing a liter of juice at year 1 is 0,34 €. The cost of labor is 12.8% of the overall cost while the cost of utilities is 9.4%. Depreciation and maintenance account for 75.6% of the net cost of the process.
Such a cost structure, with fixed costs higher than variable costs, suggests scale economies where an increase in production can significantly lower the unit cost. Being most of the initial investment due to the aseptic filler, which is oversized for the production volume considered, it is straightforward to consider that having the chance of doubling the sales volume or having a smaller or cheaper filling machine, returns could improve.

3.2 Net Present Value

As only a few input data are needed, the DCF methodology is easy to adopt and widespread among industries but, besides being a perk, this triviality might be a limitation. In fact, a positive NPV means that the project is expected to generate revenues higher enough to pay back the investment and get a profit, but this expectation does not consider possible variations in the input. Significant changes in the input variables (e.g. a negative shock on revenues due to the entrance of a competitor) can invalidate the NPV. For this reason, the DCF methodology could not be the ideal technique in projects with a high level of uncertainty. The same applies to the Internal Rate of Return with the project being profitable if and only if the IRR is higher than the cost of equity.
As stated in Eq. 1, third-party financing has to be included in cashflows. Interests payment (net of taxes) have to be detracted from the operating margin. Then, changes in the nominal value of the debt are added to the margin together with depreciation. As shown in Table 1, Cashflows are always positive but at time 0 when the investment is undertaken. Cashflows increase over time because of both inflation and sales growth rate. Resulting from Eq. 2, the Net Present Value is 494,209 €, strictly positive, and the Internal Rate of Return is 9.28% higher than the cost of equity.
Being the NPV positive and the IRR higher than the cost of equity, the investment is profitable. More precisely, on a 10-year horizon, implementing the SC-CO_2 pasteurization technology will provide the firm with a stream of cashflows equivalent to receiving 494,209 € today and thus it is worth investing.

Table 1 - Cash Flows from years 0 to 11 (in €/000)

Year	0	1	2	3	4	5	6	7	8	9	10	11
Investment	-1,774											
Revenues		4,338	4,557	4,788	5,030	5,284	5,552	5,833	6,128	6,438	6,764	
Costs		- 4,352	- 4,540	- 4,739	- 4,946	- 5,165	- 5395	- 5,636	- 5,889	-6,156	- 6,435	
Interest		- 15	- 14	- 12	- 11	- 10	- 8	- 7	- 5	- 4	- 2	
Loan		- 32	- 33	- 35	- 36	- 37	- 39	- 40	- 42	- 43	- 44	
Depreciation		215	215	215	215	215	215	215	215	215	215	
Tax		22	- 2	- 28	- 35	- 37	- 28	- 39	- 41	- 43	- 44	
Cash Flow	-1,774	161	185	209	235	262	290	320	351	384	418	315

4. Sensitivity analysis

A sensitivity analysis allowing input parameters to vary according to different probability distributions has been undertaken to test the robustness of the DCF model. The adopted methodology is Monte Carlo simulation. The input factors stressed are those suggested by Turton et al. (1998): capital investment (pasteurizing plant only), sales volume, price, maintenance fee, corporate tax rate, inflation rate, cost of funding, cost of CO_2, cost of the fruit and cost of labour. The minimum and maximum values for each parameter have been identified according to Humpreys (1991) and all the probability distributions behave as a beta distribution where α and β have been retrieved by taking the base value as mode and applying the formula in Eq. 3.

$$\beta = (\alpha(1-\gamma))/\gamma \quad (3)$$

Where

$$\gamma = (X-A)/(B-A) \quad (4)$$

and X is the mode, A is the minimum value, B is the maximum value, α and β are the parameters of the probability distribution.

According to the usual definition of critical variation, variables are defined as critical if a 1% change leads to a change of NPV equal to or higher than 1% (elasticity higher than 1). Therefore, critical variables are: capital investment, sales volume, maintenance fee, price to the trade, inflation, cost of the fruit and cost of labour. Switching values in the parameter to get an NPV equal to zero, it can be seen that only variations in sales volume, price to the trade and price of the fruit can realistically nullify financial returns: only a strong decrease in the sales volume or a lower sales price or a higher price of the fruit makes the business unprofitable.

Ten thousand Monte Carlo Simulation (Robert and Casella, 2004) have been run to test the robustness of the economic analysis. The NPV is positive in 56% of the simulations.

The variables which are most likely to critically affect the profitability are the price to the trade and the price of the fruit. In fact, if we run the Monte Carlo Simulations excluding them from the critical variables the NPV is positive in 98% of the cases.

The variability in the process parameters is such that it does not affect significantly the return of the investment. Price to the trade and price of the fruit, which are the two most impacting variables, depends on market conditions and not on process working or efficiency and even a huge fall in sales, which is the third variable for magnitude of impact on the NPV, can be born without financial losses by the firm under analysis.

5. Conclusions

Implementing SC-CO_2 pasteurization for high-nutritional value fruit juice can be profitable on the medium term. Because of the high cost for an aseptic filler, the initial investment is high and the main part of the unit cost is depreciation (50.4% of the net processing cost), followed by maintenance (25.2%). On the other hand, the process itself is not expensive as it costs 0.34 €/l (0.085 €/bottle). To this amount, the cost of the untreated juice (1.61 €/l), the bottle (0.36 €/l), and overhead costs (0.85 €/l) must be added.

A 5,000,000 bottles production with a 3% yearly growth is profitable over 10 years. The value created by the project is 494,209 €. The Internal Rate of Return is 9.28 %above the cost of equity, and it confirms the profitability of the investment. Critical variables are the initial investment, the sales volume, the price to the trade, the cost of labour and price of the fruit. Among these, only the price to the trade and the price of the fruit can nullify the NPV with a reasonable variation. A 2% variation in either the price to the trade or in the price of the fruit can override the financial returns. Allowing all the relevant parameters to vary simultaneously according to their probability function through the Monte Carlo method, the NPV resulted to be positive in the 56% of the 10,000 simulations. Such percentage rises to 98% if the price to the trade and the price of the fruit are not considered among the varying parameters. In fact, both the price to the trade and the price of the fruit are variables depending on market conditions and not on the process.

Eventually, SC-CO_2 pasteurization is a profitable investment for an average firm operating in the Italian market at the current market conditions and with standard hypotheses. Even being the initial investment costly, as the operating costs are minimum, there is the chance to payback and turn profitable in the medium term. Nevertheless, it is important to highlight this study being only a first attempt in analyzing the investment in a specific plant under determined conditions (i.e. a case study). From this baseline, different scenarios can be simulated and this work contributes in identifying those minimum (or maximum) values for the project to be profitable. In this sense, the paper can contribute to providing a very simple evaluation-tool to potential investors but, on the other hand, the methodology applied can be exploited also to assess the implementation of different chemical processes and not be limited to the SC-CO_2 pasteurization. Moreover, the wide range of application of this methodology allows to compare different potential implementations and provide the firm with data-driven investment choices.

Further analyses shall focus on elaborating a dynamic evaluation model that includes investment flexibility options (e.g. reconversion, scalability, etc.), that presents a trade-off between simplicity and information power, but it’s worth contributing to a more careful investment evaluation process in the specific market.

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