Approaching the Integrated Waste Management in a Natural Juices Company within the Framework of Cleaner Production

IOANA A. NEGROIU[1] CORNELIA A. BULUCEA[1]
CARMEN A. BULUCEA[2] IONEL L. ALBOTEANU[1]

[1] Faculty of Electrical Engineering, University of Craiova
ROMANIA
[2] Faculty of Medicine, University of Medicine and Pharmacy of Craiova
ROMANIA

alinanegroiu88@gmail.com , abulucea@gmail.com ,
carmen.bulucea@gmail.com , laurentiual2002@yahoo.com

Abstract: This paper addresses some aspects illustrating sustainable energy and matter conversion processes within a natural juices company. Increasing efforts are being expended to enhance the sustainability of technologies for fruits and vegetables processing systems, and supporting a sustainable waste management is a key way of thinking towards cleaner production. Following the idea, this paper addresses some aspects of the manufacturing processes sustainability within a natural juices company. The fruits fermentation process and the best available techniques to obtain natural juices are presented. A systemic approach of the technological flux in a natural juices company is carried out, emphasizing the inputs and outputs, as well as the co-products and waste at all stages of the manufacturing process. The paper supports the findings that within the framework of cleaner production a systemic approach of the fruits and vegetables processing enhances the sustainable operation of a natural juices company.

Key-Words: cleaner production, fruits fermentation, industrial ecology, natural juice, waste management

1 Introduction

Based on the strong conviction that a sustainable industrial metabolism should be one of the greatest of humanity nowadays, one could follow the notion that so far the Nature generated ordered structures highlighting no-waste processes of life forms. Learning from the Nature might suggest that Sustainable Development is a methodology that attempts to encompass environmental protection solutions [1-3]. The main tools to implementing sustainable development are cleaner production (CP), 7Rs Golden Rule, industrial ecology (IE) and environmental impact assessment (EIA) [2].

Within the framework of cleaner production and industrial ecology an approach of anthropogenic activities according to the pattern of the ecosystems is aimed [4-10].

According to the term defined by United Nation Environmental Programme in 1990, cleaner production (CP) requires a new way of thinking about processes and products, and about how they can be made less harmful to humans and the environment [2,10]. Consequently, CP is a "win-win" strategy since it is not against economic growth but it suggests a sustainable growth [2, 10]. Therefore CP focuses on environmental protection and natural resources preservation, such as water, energy and raw materials by implementing the best available techniques (BAT) to improving operating industrial efficiency and avoiding the end-of-pipe treatments. In order to move towards sustainable development, within the conceptual framework of cleaner production improvements of technology and changes in equipment design should suggest better choice in use of materials and energy in manufacturing and operation of industrial systems [11-12]. Improved control and automatisation represent key concepts of cleaner production strategies [1,4,11]. Green products and systems are generally produced in a manner that consumes fewer natural resources or uses them in a more sustainable way, and they may involve high exergy efficiency in their manufacture and operation [1,3,9,11-15].

Promoting CP is about improving technology and also about changing attitudes that might be seen as the most important challenging and important step to achieve a risk reduction to humans and our natural environment [2, 10].

Nowadays manufacturing processes of products involve utilization of raw materials from various sources. Rapid increase in volume and types of solid and hazardous waste as a result of continuous economic growth, urbanization and industrialization is rising concerns, becoming a key problem for local, national and international authorities and citizens as well, in order to ensure an effective and sustainable management of waste [13-18].

In line with this idea a new approach of a sustainable industrial metabolism can and should be carried out within the framework of industrial ecology (IE). As a science IE is rooted in systems analysis [2,4-9] and its novelty value is that it searches for analogies between industrial systems and the natural ecosystems. It has resulted therefore the concept of industrial ecosystem, and within the framework IE the study of an industrial system is performed more like natural ecosystems. A natural ecosystem evolves in such a way that any available source of useful material or energy will be used by other organisms within the same system or different natural systems. Animals and plants live on each other's waste, and the materials and energy flow in a complex web of interactions. This way an industrial ecosystem could be in a state of minimum entropy production, that is, the system is functioning in a state of minimum exergy destruction [2-3,9,11-12].

Consequently, within the framework of cleaner production and industrial ecology the solid waste can and should be seen as secondary resources that might become through recycling processes the raw materials for distinct manufacturing organization. One could highlight that solid waste is mainly composed of organic materials and recyclables like glass, paper, metals and plastics [14,16-20]. Still, despite the key role of waste management systems for becoming a circular economy, a continuous and consistent reporting of waste treatment capacities on a European level is lacking [17,21].

This paper is focusing on highlighting the mitigation at source of solid waste within a natural juices company that applies the best available techniques within the framework of cleaner production.

2 Systemic Approach of CP Techniques in a Natural Juices Company. Sustainability Assessment

Cleaner production techniques are focusing on rethinking for products, processes and services in order to conserving raw materials and energy, reducing the quantity and toxicity of all emissions and solid waste during a manufacturing process, as well as on mitigating environmental impact along the entire life cycle of the product [2,4,16].

2.1 Process of Fruits Fermentation

Since ever vegetables and fruits are promoted by humankind as having numerous benefits for the health. Nowadays it is widely accepted that fruits and vegetables include a diverse group of plants foods that are varying in content of energy and nutrients. Medical studies have shown that fruits and vegetables supply dietary fiber to an organism that leads to lower incidence of cardiovascular disease and obesity. It is also demonstrated that vegetables and fruits provide vitamins and minerals to the diet and are sources of phytochemicals that are acting like antioxidants, phytoestrogens and anti-inflammatory agents [22-24].

Fruits and vegetables are widely consumed by humans in the form of natural juices obtained from fermentation processes. As it is generally known, fermentation is a mostly an anaerobic process carried out by microorganisms or cells [22-24]. The fermentation of food has been used by humans for thousands of years in order to preserve foods. The fermentation process of fruits and vegetables enhances their nutritional quality and contributes to beneficial compounds such as vitamins. The bacteria in fermented foods are considered probiotics which have positive effects on human health, such as: positive impacts on immune system, improvement of intestinal inflammatory disorder, loss in weight [22-24].

It is widely accepted that sustainable development must focus on environmental and humans health issues as well. Consequently, the management of a company producing natural juices should encompass techniques for a sustainable manufacturing process along with a high quality healthy product. Definitely it is difficult to merge the economic and environmental concerns, still there are companies that work within the framework of cleaner production and also respect all sustainability requirements for obtaining a healthy product, as a natural juice is. B-Fresh Company from Newport, England, UK [25] is an example of applying a sustainable management in the natural juices manufacturing processes. Since apple juice is one of the healthiest natural juice further we briefly point out the good practice of the apple fermentation process control within B-Fresh Company.

According to company procedures [25], there are used randomly-chosen apples, but ensured that they are of a similar size using the fruit grading rings, as in Fig. 1. Then there is combined the juice of the three randomly chosen apples, to make 1 x juice sample in a beaker (see Fig. 2).


Fig.1. Fruit grading rings


Fig.2 Combined juice

It always must use measure the juice at the same temperature, ideally 15.5°C, but whatever works best is fine. Then must be measured the °Brix of 1x juice sample on intake, and every week, using a Refractometer, like in Fig.3.

Fig.3. Refractometer for juice sample

The obtained results [25] are added in the table from Fig 4.

Apple Fermentation Check Sheet
(Digital data entry)

Lot No.	Example				Arrival Date:	01/01/2014			
Juice Sample From 3 x apples	°Brix at Storage Period (weeks)								
	0	1	2	3	4	5	6	7	8
Original Sample	12.2	12.5	12.6	13.2	14.2	14.5	15.2	14.3	13.5
Retest 1 (If applicable)								14.2	13.2
Re-test 2 (if applicable)								15.1	13.0

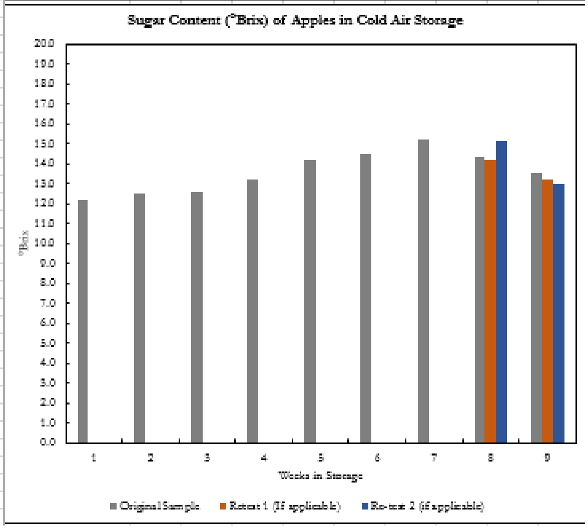

Fig.4 Control sheet of apple fermentation

Then it is analyzed and interpreted the control sheet. If the °Brix increases, this is OK, as the starch is converting to sugars [25]. If the °Brix decreases, this will be the indication that apples are fermenting – converting the sugars to alcohol.

One should note that if this happens, there must be repeated the measurement twice with 2 x fresh samples. In the event that two of the three samples having a °Brix being equal to or higher than the previous week's measurement, the apples are OK, but may be about to ferment. In the event that two of the three samples having a °Brix being less than the previous week's measurement, it is very likely that the apples are starting to ferment.

2.2 Implementation of Best Available Techniques

The UNEP launched the Cleaner production Program in 1989 [1-2,10] as a response to the need to reducing worldwide the industrial pollution and waste. The benefits of applying CP techniques consist not only on reducing waste disposal cost and raw material cost, but also on improving company performance and helping comply with environmental protection regulations.

Thermal methods, traditionally used in the food industry for food preservation, carry disadvantages like vitamin destruction or flavour changes [22-24]. The food industry is increasingly moving toward new product development and innovative propositions through new processing methods that allow doing things you could not do before [22-24]. To meet the demands of the 21st century consumer (convenience foods, higher sensorial and nutritional quality, additive free/natural, functional products, etc.), food companies need to innovate by using the latest non-thermal technologies, and High Pressure Processing is the most relevant Best Available Technique. Definitely, in the field of fruits and vegetable processing one of the most successful developments made to date is High Pressure Processing (HPP).

High Pressure Processing is a cold pasteurization technique which consists of subjecting food, previously sealed in flexible and water-resistant packaging, to a high level of hydrostatic pressure (pressure transmitted by water) up to 600 MPa / 87,000 psi for a few seconds to a few minutes. It is the same effect as subjecting the food to an ocean depth of 60 Km deep -if an ocean this deep existed [22,26].

Although the Non-Thermal Pasteurisation effect of high pressure on foods has been known since the 19th Century, it was not until the 1990´s that the first HPP products were developed. Since 2000, High Pressure Processing has been successfully implemented in all type of food industries worldwide [22-26].

High Pressure Processing is among the Best Available Techniques in the field of food processing since HPP is a natural, environmentally friendly process that respects the ingredient and helps maintain the fresh food characteristics like flavour and nutrients. It is a real alternative to traditional thermal and chemical treatments [22,26].

One could note that High Pressure Processing (see Fig.5) is a cold pasteurization technique by which products, already sealed in its final package, are introduced into a vessel and subjected to a high level of isostatic pressure (300–600MPa/43,500-87,000psi) transmitted by water [26].

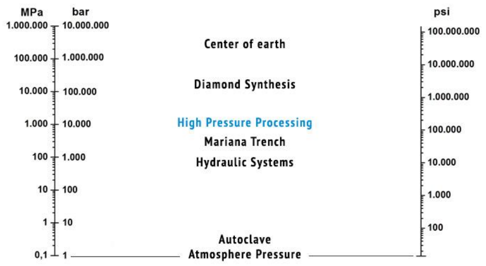

Fig.5 HPP Technology

Pressures above 400 MPa / 58,000 psi at cold (+ 4ºC to 10ºC) or ambient temperature inactivate the vegetative flora (bacteria, virus, yeasts, moulds and parasites) present in food, extending the products shelf life importantly and guaranteeing food safety. High Pressure Processing respects the sensorial and nutritional properties of food, because of the absence of heat treatment, and maintains its original freshness throughout the shelf-life.

In Fig.6 it is depicted the diagram of operation of a HPP unit:

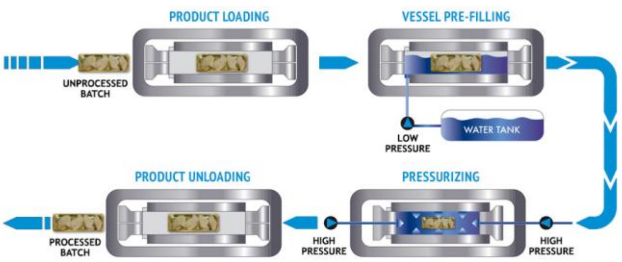

Fig.6 Diagram of operation of a HPP unit

Within the framework of cleaner production one should highlight the High Pressure Processing Technology (HPP) main advantages [22-23,26]:

- Characteristics of the fresh product are retained, sensorial and nutritional properties remain almost intact, and as a result we have a greater food quality.
- Destroys pathogens*(Listeria, Salmonella, Vibrio, Norovirus, etc.)*, consequently resulting food safety and exportation.
- Extends product shelf life, resulting lower returns, improved customer satisfaction.
- Reduces drastically the overall microbiological spoiling flora that means higher quality along shelf life.
- Avoids or reduces the need for food preservatives, resulting clean label foods (Natural/Additive Free).
- New innovative food propositions. Products that can not be thermally treated can now be High Pressure Processed, meaning innovation and competitive advantages.
- Able to shuck molluscs or extract crustacean meat without boiling that means higher yields, fresh flavour, minimum hand labour.
- Only needs water (which is recycled) and electricity which means environmentally friendly.

2.3 Critical Control Points in Production Processes

HPP is popular because it reduces microbial loading of the subject, and preserves the organoleptic properties, the latter being lost during thermal processing. The result is a product with a reduced microbial count, but with more retained flavor than one which has been heat-treated [22-26]. Furthermore, HPP is used once the product has been packed, so there’s no handling of the exposed product post treatment. Factoryuse 600 MPa (6000 bar) for 3 minutes, in-keeping with commercial practices.

The high pressure inactivates vegetative microorganisms. This is achieved by changing the morphology, biochemical reactions, genetic mechanisms and cell membranes and cell walls of microorganisms, rendering them inactive. This does not generate a total kill of all micro-organisms, but a large reduction is observed. In our own trials of juices, we have observed TVCs (total viable counts) of 10^6cfu (colony forming units) in un-treated products, and between 10^3 and *ca* 10 cfu in HPP treated juices, a 3 to 5 Log reduction in microorganisms [22-26].

There are limitations, in particular HPP does not kill spores; the pressures needed to kill spores are so great that they are not yet available in a commercial method. However, spore development is reduced by low pH, and we produce our juices with a pH <4.6, the critical value below which spore development is minimized.

In addition to HPP and pH <4.6, the third control measure is low temperature storage and display. With the juices kept at the normal cool chain of <5°C, the low microbial levels observed in the factorytrials after HPP treatment remain at 10^3 or less for 4 weeks, meaning that any remaining microbial populations do not appear to be growing in any significant way during shelf life. This is important for food safety, and with the advantage in that it reduces the risk of bottles bursting on the shelves due to gas build-up resulting from microbial action.

The pH and the HPP are CCP(Critical Control Points). It is acknowledged that whilst High Pressure Processing (HPP) controls bacteria, HPP does not control spores. To control spores, juices are produced with a pH <4. 6, and this is confirmed in the completed juice prior to HPP [22-26].

Industrial metal detectors are used in the pharmaceutical, food, beverage, textile, garment, plastics, chemicals, lumber, mining, and packaging industries.

Contamination of food by metal shards from broken processing machinery during the manufacturing process is a major safety issue in the food industry. Metal detectors for this purpose are widely used and integrated into the production line.

2.4 Manufacturing Process Description

A good practice is achieved by an efficient production process, with respect to the resource consumption (raw materials, energy and water) and waste generation [2,10].

As we already emphasized in previous sections, in an industrial company, the cost-benefit ratio plays an important role since sustainability aspects are related to value. Consequently, recycling and reuse of co-products and waste are important aspects in the manufacturing process sustainability.

In line with this idea, a systemic approach of the technological flux in a natural juices company is carried out, emphasizing the inputs and outputs, as well as the co-products and waste at all stages of the manufacturing process.

The first stage of the technological flow is the supply.

There are 2 kinds of supplies at the delivery:

- perishable materials (such as vegetables and fruits used to produce juice), and

-the non-perishable materials (here comes everything you need to pack the dough itself).

With respect to perishable materials one could highlight that being a natural juice factory, perishable materials are the key to the product itself. We all know that in order to get a good final product with a good taste we must use good quality ingredients. But good quality should not mean a high production cost. The difference between quality I and quality II is made by the relationship between appearance and taste. If the quality I products have extraordinary appearance and taste, in quality II, the appearance matters less, the taste of the product being the main target. Therefore, the quality of the perishable materials used in this plant is of the 2nd quality. For example, apples that come from a fruit tree farm and can not be sold individually are stored and used for juice or jam making (see Fig.7).

Fig.7 The 2nd quality apples for juice production

The same process takes place in other raw materials used in this plant (apples, carrots, red beets, spinach, lettuce, kale, lemon, ginger, lime, oranges, as can be seen in Fig.8).

Fig.8 The 2nd quality fruits and vegetables for natural juices production

Regarding the non-perishable materials, our sustainability scenario in a natural juices company suggests the utilization of plastic bottles, plastic caps for the bottles, box labels and cardboard boxes and foil used for packaging the finished product (Fig.9). We aim that 75% of the non-perishable materials used are made of recyclable materials.

Fig.9 Non-perishable material for natural juices production

Further we depict the stages of the technological flow in a sustainable company that produces natural juices. In the chart below (see Fig.10) through rectangles there are presented all inputs for the manufacturing stages, and also are emphasized the waste generation at any production stage.

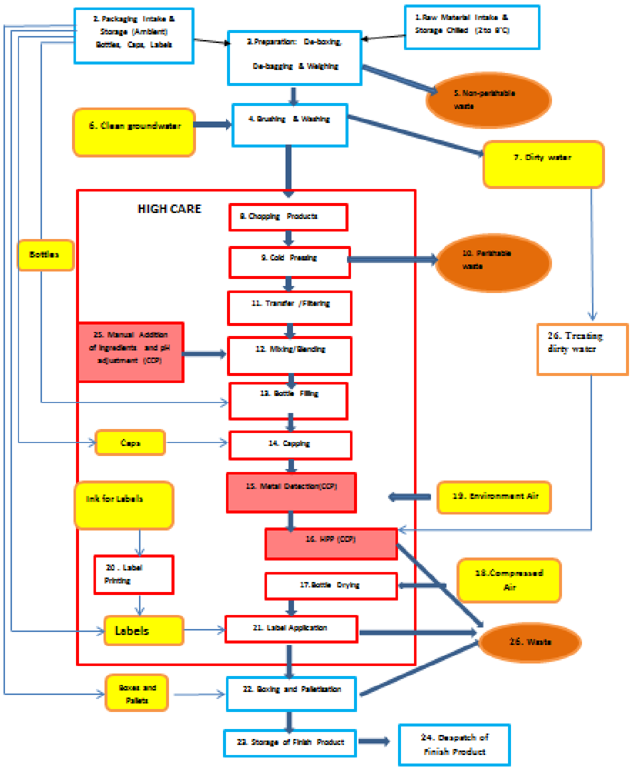

Fig.10 Manufacturing flow chart

1. Raw Material Intake & Storage Chilled (2 to 8°C)
2. Packaging Intake & Storage (Ambient) Bottles, Caps, Labels
3. Preparation: De-boxing, De-bagging & Weighing
4. Brushing & Washing
5. Non-perishable waste
6. Clean groundwater
7. Dirty water
8. Chopping Products
9. Cold Pressing
10. Perishable waste
11. Transfer /Filtering
12. Mixing/Blending
13. Bottle Filling
14. Capping
15. Metal Detection(CCP)
16. HPP (CCP)
17. Bottle Drying
18.Compressed Air
19. Environment Air
20 . Label Printing
21. Label Application
22. Boxing and Palletisation
23. Storage of Finish Product
24. Despatch of Finish Product
25. Manual Addition of ingredients and pH adjustment (CCP)
26. Treating dirty water
27. Waste from HPP, label application and boxing and palletisation stages.

2.5 Sustainable Waste Management

The waste is part of a substance or a material resulting from a technological process of making a product unusable in the same process [13-18]. From its source one could highlight the types of waste as industrial (from the processing resources through different technologies) and metabolic (from biological processes, for example manure). In urban and rural ecosystems daily results huge amounts of waste, not only make space problems for aesthetic storage, but are also a source of pollution threatening human health. All waste degrades the environment, contaminate groundwater (storage method makes possible infiltration of rainwater, which causes pollutants and pathogens).

Within the framework of IE and CP an industrial ecosystem exhibits a high degree of material loop closing [2,5-9]. Materials are circulating through a web of interconnected industrial ecosystems, and the waste of a system becomes the supply for another interconnected system.

In line with previous idea we follow in this study the solid waste circulation accordingly to the manufacturing stages depicted in the previous section in a natural juices production company.

At the supply stage there are recycled the non-perishable materials that appear in this process, namely packaging of raw materials (eg cardboard boxes, plastic bags), as in Fig.11. They are stored at collection points and then sent to recycled or reused wood chambers.

Fig.11 Non-perishable materials recycling in the natural juices production process

Further we prone on the recycling of pallets on which the materials are received (see Fig.12). Depending on the color (white or blue), they are

reused for final product delivery or recycled, as below
→ white pallets are recycled
→ blue pallets are re-used


Fig.12 Reuse or recycling of pallets in the natural juices production process

With respect to the perishable waste we highlight the waste resulting during the process of cleaning and washing of vegetable materials. The diagram presented in Fig.13 depicts the circuit of the water use within the manufacturing processes of natural juices.

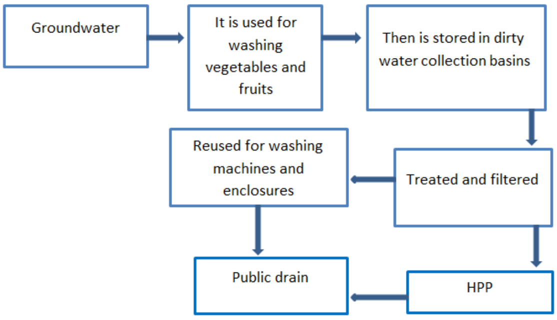

Fig.13 Water and wastewater circuit within the natural juices production process

Within a sustainable waste management approach we focus further on the waste from cold pressing process. The waste resulting from this process is pulp from the pressed materials (see Fig.14).

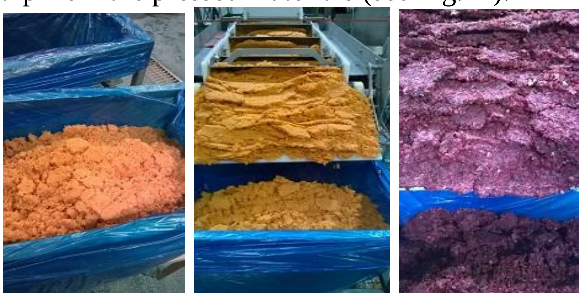
Fig.14 Waste from cold pressing process within the natural juices production

This waste is stored and reused or recycled depending on the type of material, such as:
→ the pulp from carrots and red beet is reused for the production of cereals and energy bars;
→ the pulp from citrus, ginger or curcuma is dried and used for tea bags;
→ the pulp from the rest of the material is used as animal feed.

3 Discussion and Conclusions

This paper addresses some aspects illustrating sustainable energy and matter conversion processes within a natural juices company.

Increasing efforts are being expended to enhance the sustainability of vegetables technologies for fruits processing systems, and supporting a sustainable waste management is a key way of thinking towards cleaner production.

This paper addressed some aspects of the manufacturing processes sustainability within a natural juices company. The vegetables fermentation processes and the best available techniques to obtain natural juices have been presented.

A systemic approach of the technological flux in a natural juices company is carried out, emphasizing the inputs and outputs, as well as the co-products and waste at all stages of the manufacturing process.

The paper supports the findings that within the framework of cleaner production a systemic approach of the vegetables processing enhances the sustainable operation of a natural juices company. Based on the rules of industrial ecology it is important to identify and follow over the whole technological flux the specific inputs, outputs and waste at any stage of the manufacturing process.

The study aims to highlight that future needs for sustainable development are likely to take into consideration the interactions between human applications and environmental factors.

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