Scale up models and processes

Deliverable D6.5

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List of abbreviations

AD	Anaerobic Digestion
EU	European Union
FA	Framework for Action
PWP	Pilot Working Platform
WP	Work Package

1 Executive Summary

1.1 Objectives of work

REFRESH is an EU H2020 funded research project (which runs for 4 years until June 2019) taking action against food waste. One of the intended key strategies is upgrading of side streams from food processing to food ingredients and other valuable applications.

This piece of analysis sits within REFRESH Work Package 6 (WP6): Valorisation of waste streams and co-products. The final objective of this Work Package is to increase the exploitation of food and packaging waste by helping business stakeholders to identify in which conditions a valorisation option is (economically) feasible by *providing clear guidance on cost-benefits of valorisation (WP6_Obj6)*.

Assessing practical economic feasibility of new valorisation options often falls short through (1) leaders of novel valorisation pathways presenting incomplete costs models (thereby underestimating costs) and (2) insufficient awareness of economies of scale, often turning out disadvantageously for (small scale) innovative solutions. Through a case study this REFRESH WP6 deliverable presents a methodology for a well-underpinned assessment of practical economic feasibility.

1.2 Approach

A techno-economic analysis combines establishing all unit operations within a suitable industrial processing chain (process flow diagram) with estimating capital and operational expenses for such processing chain to indicate its prospective technical feasibility and profitability. End-product cost estimates can be derived from the resulting economic model. Through scaling factors, the effect of scale size on product cost price is also shown.

The analysis method is founded on recognised standards as formulated by amongst others Sinnot (2005) and Woods (2007), originally aimed at chemical processing industries. Engineering analysis estimates drafted this way have typical accuracy +/- 25 to 50% of the actual project capital costs (see e.g. see e.g. Couper *et al.*, 2010). We have extended these sets of practical cost price models for chemical processes with price models for typical food, feed and biobased processes based on newest business case data from practical projects and latest literature.

In this way costs of producing food waste derived product can be estimated and compared to prices of existing products in the market (replacement product). This gives an idea of the potential market position of the food waste derived product.

In this report the approach is presented on a practical case: producing a food ingredient from a chicory processing by-product.

> ***Remark*** Any investment-related decisions in new valorisation approaches will also depend on other facts, amongst which are attributes of quality, such as future market predictions and product quality (comparison of flavour and consistency, perishability, etc. of the food-waste derived product and competing products).

1.3 Typical results: conclusions from the case study

The case study – producing a food fibre from chicory extraction residues – shows that scale size is critical for producing the fibre at a competitive price compared to replacement product (dietary fibres) in the market. Actually at the volumes generated by a large chicory processing plant, Sensus in The Netherlands, sufficient volume is available to reach such scale.

Because the product is a new food ingredient, it is expected that market development to full scale may take a number of years. Results show that a gradual production start may demand for a significantly higher product price (typically €0.15 per kg extra in the studied example).

In the actual decision process, however, the commercial partner decided not to develop the process because the new fibre product would was not deemed sufficiently superior to compete with existing fibre products unless additional (cost price enhancing processing) would be applied.

1.4 General conclusion on methodoly and next steps

The presented methodology is used for other cases presented in diverse REFRESH deliverables:

- converting food waste from food service to animal feed (deliverable D6.11),
- analysing conditions for high-value valorisation, specifically tomato side streams (deliverable D6.12).

The method is available for application to other cases.

2 Introduction

2.1 REFRESH

REFRESH is an EU Horizon 2020 funded research project (which runs for 4 years until June 2019) taking action against food waste. Twenty-six partners from 12 European countries and China are working towards the project's aim to contribute towards Sustainable Development Goal 12.3 of halving per capita food waste at the retail and consumer level and reducing food losses along production and supply chains, reducing waste management costs, and maximizing the value from un-avoidable food waste and packaging materials.

This piece of work sits under Work Package 6 entitled "Valorisation of waste streams and co-products".

2.2 Aim of Workpackage

WP6 – Valorisation of waste streams and co-products

The aim of the workpackage is to increase the exploitation of food & packaging waste by:

- helping business stakeholders to identify waste streams (organic and packaging) that are appropriate to valorise due to their robustness of supply, quality and composition, and for which products and outputs might be realised that are technologically feasible, economically viable, legislatively compliant and environmentally sustainable/beneficial;
- valorising post-consumer putrescible waste
- helping policy makers to identify and implement improvements to the legislation that will reduce unnecessary restrictions on valorisation (including use in feed production, whilst maintaining appropriate safety and quality standards).

2.3 Description of related tasks

This assessment constitutes part of the task T6.3 and final task (T6.5) and objective within REFRESH Work Package 6 (WP6_Ob6): to create a demand orientated assessment of valorisation approaches providing clear guidance on the costs and benefits [of valorisation]. It follows technical work identifying approaches for valorising a new food ingredient (REFRESH Task 6.3.2/D6.4 '*New Food Ingredients*', WP6, Objective 4) and associated pilot trials conducted for further use in model food products.

2.4 Methodology

2.4.1 Techno-economic modelling of innovative valorisation options

The first task is designing a process flow diagram including all unit operations for producing an intended food (or other valuable) product from the side or waste stream.

Different approaches are possible for this process design task:

- The design may be based on existing operational processing chains (when available). Commonly modifications will be needed because of divergent characteristics of the input material (side stream or waste) and/or end-product. Likewise, processing parameters (retention times, capacities, energy consumption, etc.) may have to be adapted. Such modifications may be done based on expert judgement, literature study and/or further process analysis.

- The design may be based on example(s) found in literature, also possibly adapted based on expert judgement, further insights from literature and/or process analysis.

- Thirdly a practical process layout may be based on lab- or pilot scale process design. Such approach involves translation of the processes/operations to practical equipment and process layout involving all individual unit operations (see example in Figure 1).

Next, the intended processing chain design is elaborated to a process flow diagram that includes all equipment (including capacities and/or dimensions of per equipment) for the unit operations, and inputs and outputs (including water, energy, additives, side streams, etc.) per processing and buffer step. The flow diagram serves for discussion/aligning the process view amongst the stakeholders.

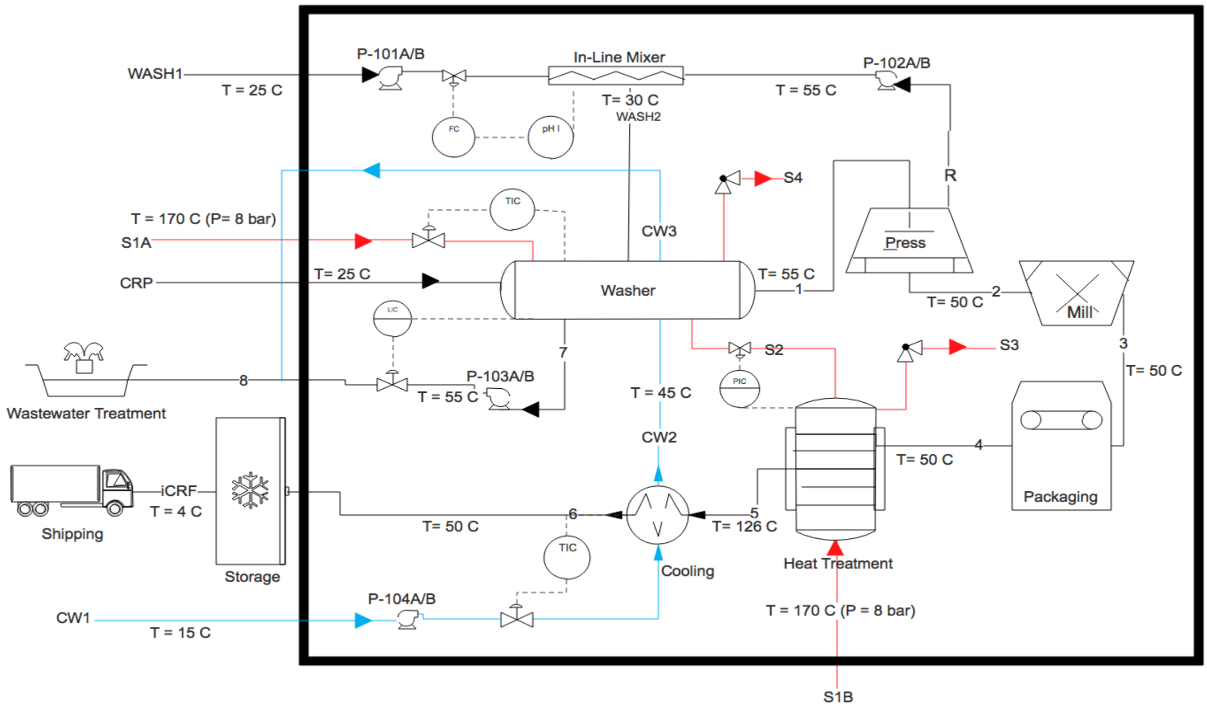

Figure 1 Initial process flow diagram produced by Fränkel (2017)

The next task is setting up a cost estimation model for the intended system. This consists of the following parts:

- Estimating equipment costs.
- Estimating total fixed capital investment costs.
- Estimating variable cost.

For estimating equipment costs, again different approaches are possible, dependent of the availability of information:

1. A model may be available from trusted sources (e.g. from literature or previous study). Through expert judgement some parameters (including cost-benefit effects) may be re-adjusted.
2. Alternatively, per unit process equipment the cost price can be estimated through cost price parameters as presented by Sinnot (2005), Woods (2007) and parameters in a dedicated database by DLO-FBR (filled with data from more recent projects).

Both a cost estimate for a complete system as well as for individual components must be corrected:

- Correcting for historic cost price developments, according to the Chemical Engineering Plant Cost Index, see Figure 2 (CEPCI, 2018).

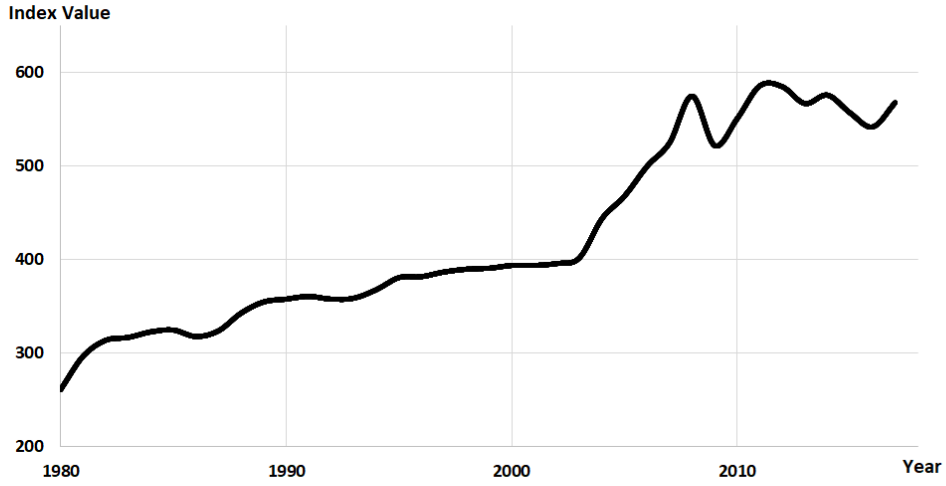

Figure 2. Annual averages of the Chemical Engineering Plant Cost Index 1980 to 2017 (CEPCI, 2018).

- Correction for scaling: correcting to dimension/capacity of an individual process equipment or the complete system. For this, the following rule of thumb is commonly applied:

$$cost_2 = cost_{ref} \left(\frac{size_2}{size_{ref}} \right)^n$$

where

$cost_{ref}$ is the equipment cost price for reference system (according to data by e.g. Sinnot (2005), Woods (2007) or in the DLO-FBR database.

$size_{ref}$ is the size/capacity of the reference system as defined in the data by Sinnot (2005), Woods (2007) or the DLO-FBR database.

$size_2$ is the size/capacity of the intended system.

n is the scaling factor. For most equipment n is smaller than 1 (explaining 'economies of scale'). For various processing equipment types this value is listed by Sinnot (2005) and Woods (2007). For missing values, as well as for combined systems an average value 0.6 is broadly accepted.

$cost_2$ is the estimated equipment cost price for the intended system.

The total equipment costs is the sum of all equipment costs.

Total fixed capital investment costs include, next to equipment costs, various other costs, like engineering costs, piping costs, buildings, legal feeds, etc. As a rule of thumb the total fixed capital costs are estimated at 3 to 5 times the equipment costs. The ratio of total fixed capital investment costs to equipment costs is called Lang Factor, with default value 4.

Variable costs are related to labour, energy, water, chemicals and other co-inputs, maintenance, waste, etc. Estimates are available in the literature cited above for some of these rules of thumb, but others must be estimated.

Engineering analysis estimates drafted this way have typically accuracy +/- 25% of the actual project cost (see e.g. see e.g. Couper *et al.*, 2010).

2.4.2 Analysing outcomes of economic analyses – consequences for practical feasibility

Based on the cost model obtained according to above methodology various analysis can be made:

- Scaling analysis shows how the final product cost price depends on scale of production. This supports decision taking by an entrepreneur on small-scale production for specialty market or large-scale production. Potential disappointment on small starting initiatives (with consequently relatively high product cost price) may be prevented through this knowledge.
- Analysis of business growth paths: through cash-flow analysis with partly utilised plant capacity during first years of operation (thus with taking full fixed costs in consideration but reduced variariable costs in the early stages of operation).
- Comparing different technology options.

This methodology forms a bridge between technological solutions development and practical realisation. And although the cost-benefit analysis cannot be expected to be highly accurate, still they give largely more insight than only an input-output model would do.

Disclaimer:

Below work is intended to demonstrate the use and practical benefits of applying techno-economic methodologies for valorisation approaches. Specifically, it shows how choices of technology and volumes affect cost price. However, any investment related decisions in new valorisation approaches will depends on other facts, amongst which are attributes of quality, such as flavour and consistency compared to competing products, but also future market predictions. These, additional conclusions, not addressed here are needed by any investing party. In this particular example the conclusion from the commercial partner was that product

quality in the end was a decigfin factor and it was not deemed sufficiently competitive to exising fibre products in the market with processing applied.

3 Results

We present the methodology on different scenario's for chicory root processing to a food ingredient:

- processing chicory fibre to a dried dietary fibre
- processing chicory fibre to a wet dietary fibre product
- comparing scenario with direct full capacity use to a scenario with 5 years capacity filling phase.

3.1 Chicory Root rest product processing to food ingredient

In the considered case the new food ingredient is derived from chicory root fibre, a by-product of manufacture of Inulin based food products. This fibre is currently utilised as a low value co-product agricultural feedstuff or spread to support soil fertility. Part of the value of it's current uses are somewhat masked in the reduced waste disposal cost burdens which would otherwise be incurred (Roode, 2015).

Sensus, a Dutch agroprocessing company, manufactures inulin from the root of the chicory plant by means of extraction with hot water. 40 million kilograms (40 000 tons) of chicory is processed annually during the harvest time: September to January.

The residue, spent chicory root, has high content of fibers and a small amount of non–extractable inulin and protein. The pulp is commonly traded as animal feed and soil fertilizer, with only small revenues for Sensus.

In dialogue by students with stakeholders from Sensus options for valorisation as food ingredient were explored. This product can contribute to satiety in drinks and cereal bars, even better than conventional carbohydrates (Roode, 2015), therefore reducing total daily calorie intake. A process that produces wet pulverised fibres as fresh ingredient for a chicory-fibre enriched dairy drink was designed (Fränkel, Pilachan & Van, 2017, Appendix A of this report). In that study a reference market potential (15 kton wet fibres, equivalent to 4 kton dry material) was based on a hypothetic market position: 11 million economically active consumers (ages 15-64 years), of which 13% consumes 1 liter of the fibre-enriched dairy drink per week. This volume is about 1/3 of the total annual production of the byproduct by Sensus.

For REFRESH the analysis is narrowed down to upgrading the by-product to a food ingredient, leaving the application in a consumer product to a third party:

- This REFRESH analysis is applied to upgrading the chicory pulp to a wet or dry food ingredient; costs and benefits of production of a consumer product are left out of the analysis. For competiveness a comparison with other dietary food fibre ingredients prices is made.
- Costs of dried as well as wet fibre products are considered; the first requiring a drying stage and the latter requiring frozen storage.

- The processing period was limited to the common campaign period (typically 100 days per year from half September to end December; appropriate dimensioning of the processing equipment is required.

3.2 Assumptions

Assumptions in the calculations (based on the students report, Appendix 1):

- Dry matter content of the fresh and refined chicory fibre product is estimated at 25%.
- Equipment costs for reference plant scale size (15kton input per year, prive level of year 2005)
    - washer/boiling tank k€ 11
    - boiler k€ 24
    - press/centrifuge k€ 39
    - pulveriser k€ 41
    - dryer k€ 325 (Woods, 2007)
- Costs of frozen storage: €70 per tonne.
- Equipment costs scaling factors vary from 0.35 (for the pulverizer) to 1 (for the press/centrifuge).
- Lang factor (total capital costs vs. equipment costs): 3.15.
- Price corrections for 2019 vs. 2005 (based on Chemical Engineering Plant Cost Index): +40%.
- Energy costs:
    - boiler: 0.6 MJ heat per kg,
    - centrifuge: 0.002 MJ electricity per kg,
    - pulveriser: 0.004 MJ electricity per kg,
    - dryer: 4 MJ heat and 0.15 MJ electricity per kg water evaporated,
    - Energy prices (CBS statline, staline.cbs.nl, average for 2018, large users, including taxes, excluding VAT):
        - electricity 0.056 euro per kWh, that is 0.0156 per MJ,
        - natural gas 0.007 euro per MJ heat.
- Labour costs: k€400 and k€500 for the large scale plant (capacity 15kton/y), decreasing to ¼ for small scale (when the valorisation is a side-activity of the main plant, and operators and other personnel can supervise this plant.
- Other plant related annual costs: estimated at 15% of the equipment costs plus 10% of the other fixed capital costs.

- Replacement product in the market:

  The product is intended as a dietary fibre food ingredient with relatively high water holding capacity (WHC): for undried fibres the WHC is comparable to citrus fibre (Fränkel et al, 2017). For dried fibres the WHC seems somewhat reduced (REFRESH D6.4), however, the authors claim that the WHC properties most likely will be improved when using more suitable drying methods (making the WHC comparable to undried chicory fibres).

  Typical bulk prices for citrus fibre vary from €200 to €600 per ton for unspecified quality[1], to €3 per kg[2] and €5 per kg[3] for branded products. For a corn-based soluble fiber we found a bulk price of €2 per kg[4].

- Avoided income of current destination (animal feed): A reference price for liquid feed is €0.20 per kg dry matter[5], that is €0.05 per kg wet material. After subtracting transportation and marketing costs for the feed – estimated around €20 per tonne – the gate prices come down to €0.12 per kg dry matter.

3.3 Results

3.3.1 Economic analysis of dry dietary fibre production

Based on above assumptions the (bulk) cost price of dry fibre food ingredient is calculated for different production volumes (assuming full capacity use of the process line).

Effect of scale size on the production costs, for two depreciation periods are shown in Figure 3. Apparently, starting at annual capacity of about 3 kton product per year the food additive can be produced at cost price between €0.40 to €0.50 per kg, which is very compatitive to cost prices of competing branded food fibre products (see section 3.2). At smaller scale, the cost price will substantially higher.

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[1] From Thailand. Minimum order 100 tonnes, https://www.alibaba.com/product-detail/HIGH-GRADE-CITRUS-FIBER_50030504274.html?spm=a2700.7724838.2017115.13.89ad3def2H7USh (visited 26 March 2019).
[2] From Germany. Minimum order 500kg. https://www.alibaba.com/product-detail/Citrus-Fiber_50041490863.html?spm=a2700.7724838.2017115.9.329416b1gCQxHc (visited 26 March 2019).
[3] Citri-Fi®, a citrus-derived fibre product (Fiberstar), is typically priced around €5/kg (bulk supply to India, derived from https://www.zauba.com/import-citri-fi-hs-code.html, visited 5 March 2019).
[4] Promitor® soluble fibre (Tate & Lyle) is priced around €2 per kg (bulk, prices 2014-2015, https://www.zauba.com/import-promitor-hs-code.html, visited 25 February 2019).
[5] Derived from www.duynie.nl for liquid pig feeds in NL, and https://www.tridentfeeds.co.uk/news-events/news/liquid-feeding-value-an-opportunity-this-winter/ in UK (1 February 2019).

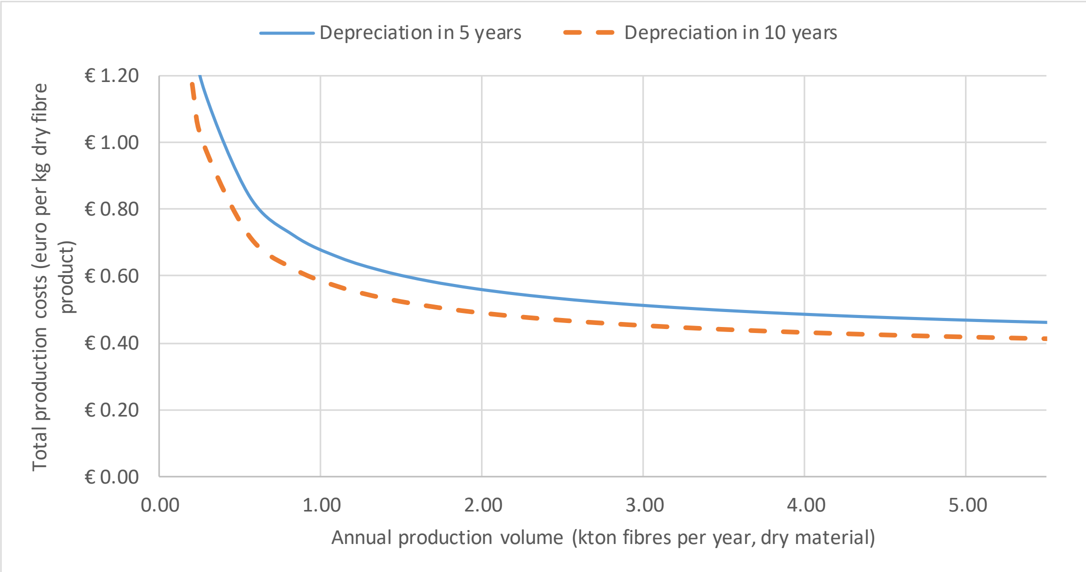

Figure 3. Estimated production costs of dried chicory fibre food ingredient for varying scales of operation.

The cost price only weakly depends on the depreciation period. Apparently the initial fixed capital costs are not very high compared to the annual operational costs. This is confirmed by the actual data (Figure 4).

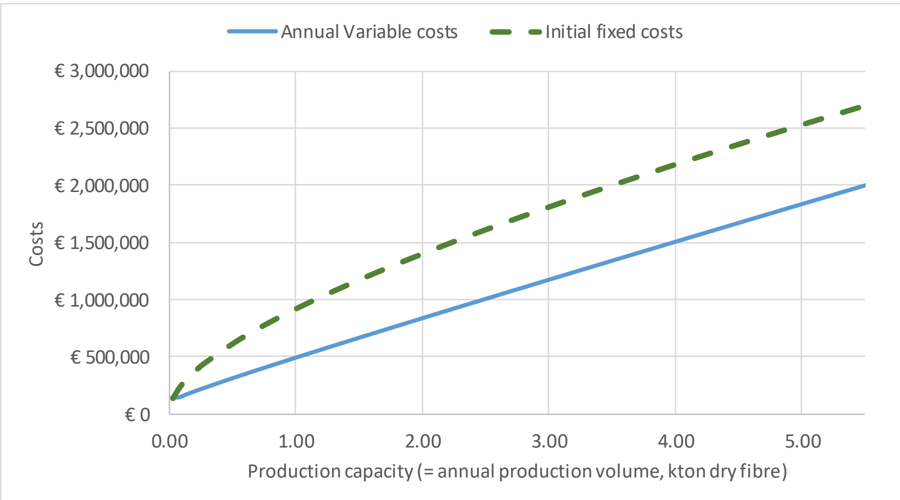

Figure 4. Comparison of initial fixed costs and annual operational cost.

3.3.2 Economic analysis of wet dietary fibre production

The cost price for the wet fibre product lies quite close to that for the wet fibre (Figure 5).

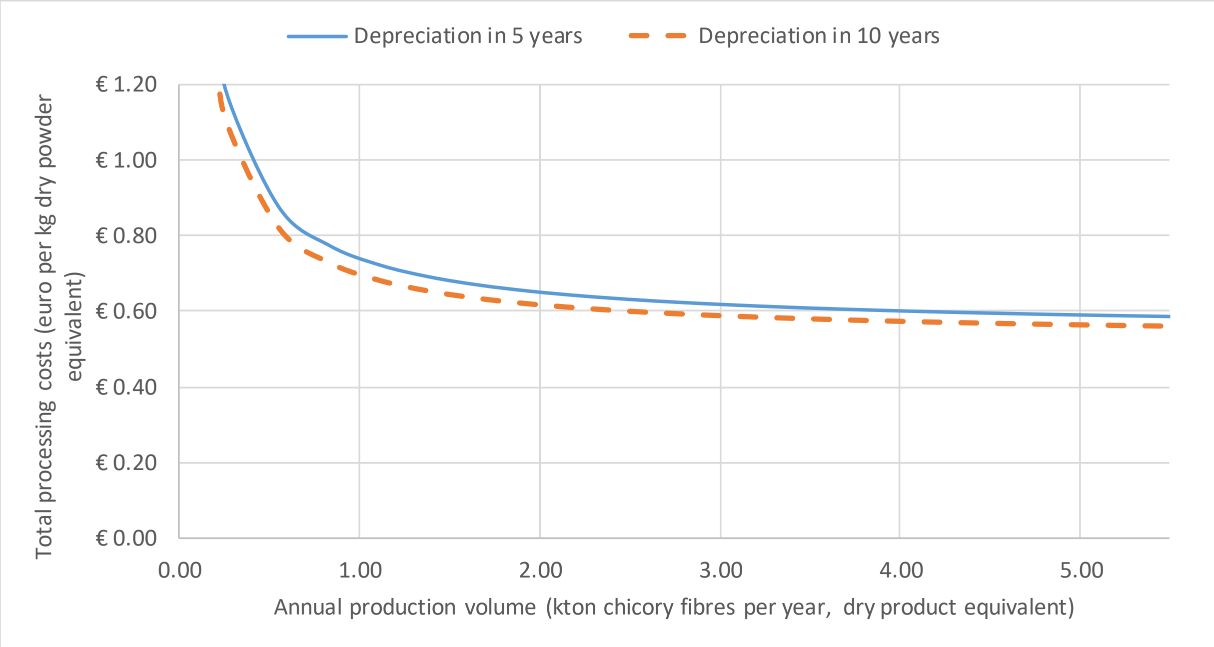

Figure 5. Estimated costs for production plus frozen storage of wet chicory fibre food ingredient for varying scales of operation.

3.3.3 Comparing wet and dry fibre production

For larger production capacities, the costs for the wet product appears somewhat higher than for the dried product (Figure 6). This is due to the costs of frozen storage, which are – except for the smallest volumes – significantly higher than the costs associated to drying.

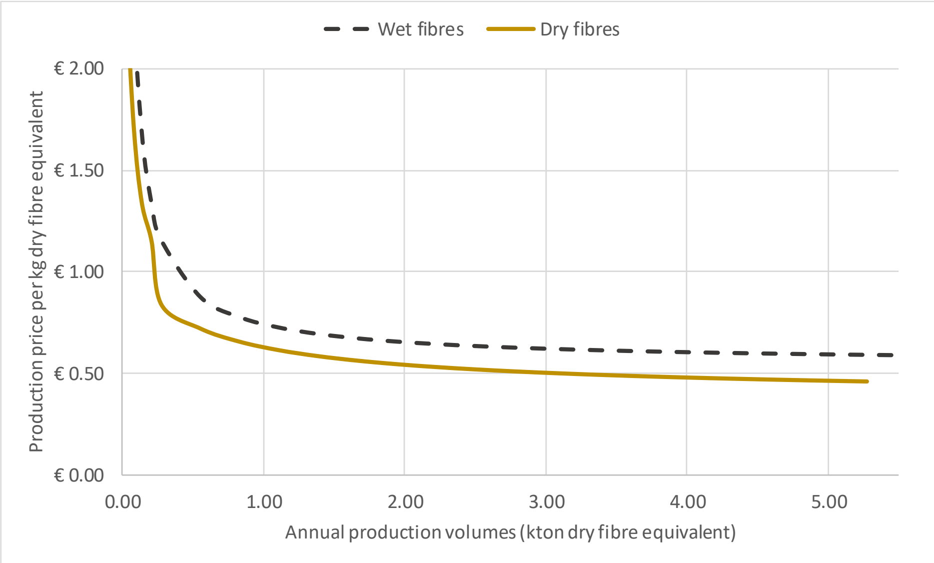

Figure 6. Comparison of production for dry and wet fibres (including costs of frozen storage for the wet product), with depreciation period 5 years.

3.3.4 Comparing full-scale and gradual start-up business development

In practice a start-up activity will be gradually started. This will affect incomes and variable costs in the start-up phase. To show typical effects, the total cash flows when starting at full capacity directly and when increasing production volumes linearly during the first five years are shown in and respectively[6].

[6] Below cash flow analyses are based on cost models as described above (large scale scenario: 4.2kton dry fibres per year), assuming annual 15% depreciation.

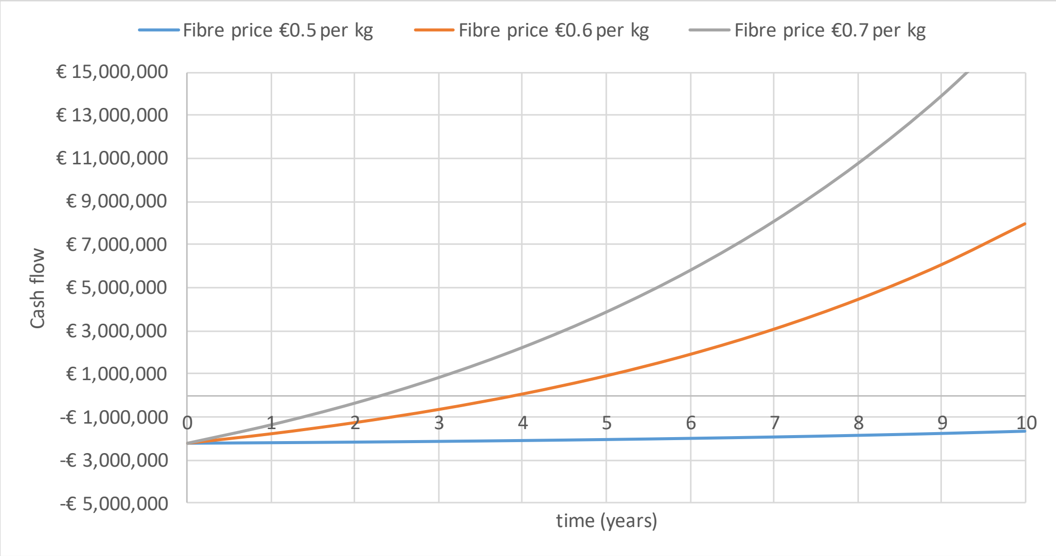

Figure 7. Cash flow analysis for production of dried fibres, for full plant capacity utilisation from start.

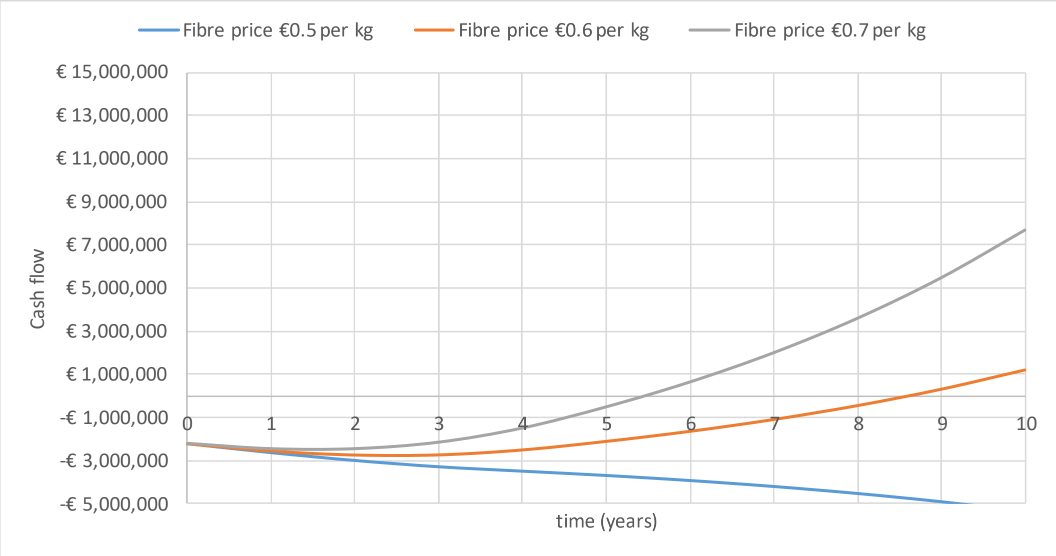

Figure 8. Cash flow analysis for production of dried fibres, assuming a business start-up period (with linearly increasing production volume to full capacity after 5 years).

Apparently a period of new market development, with only fractional use of the processing capacity will significantly affect the product cost price.

3.4 Evaluation of the outcomes for chicory-derived dietary fibre food ingredient.

Above results indicate that scale size largely influence the dietary food fibre cost price. At small scale the food fibre price is relatively high. The cost price drops quickly with increasing scale size. For about 1.5 kton and larger, the fixed capital costs become less dominant and consequently the cost price per kg product flattens: around €0.50 for the wet product and €0.50 for the dried fibre product (both per unit dry fibre equivalent). This appears quite competitive to competing dietary fibres in the market.

With a new food ingredient, it is expected that market development to full scale may take a number of years. Above results show that a gradual production start may demand for a significantly higher product price (typically €0.15 extra in above example).

4 Next steps

The approach of (scaling) process analysis gives understanding of the potential (commercial) business cases for different technology options, scale sizes and market development scenario's. With the available set of processing costs data, and scaling models such analysis is possible at the early stages of decision taking on food waste valorisation options.

Combined with judgement on product quality for the intended market (based on technical assessment), relevancy for the market and market volume (market scan), the entrepreneur can then well-founded decide about next steps.

5 Conclusions

The methodology of techno-economic analysis gives quantitative notion of expected food product cost price and effects of technological alternatives and market development. It can – next to process technology development, product application research and market analysis – support decision making on valorisation of waste streams.

Sufficient processing scale size is necessary in order produce price-competive products. Consequently, we conclude that starting new valorisations at small scale may hinder practical success because the product cannot be offered at a competitive price compared to alternatives in the market.

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7 Annexes

7.1 Annex A: Business Case study on Yoghurt and Fruit Food Product, Application of a Chicory Root Rest Stream

Student report:

Dean Fränkel, Apiwat Pilachan & Sui Mi Mawi Van (2017): Business Case: Yoghurt and Fruit Food Product Application of a Chicory Root Rest Stream, The Hague University of Applied Sciences and Sensus.

Business Case: Yoghurt and Fruit Food Product Application of a Chicory Root Rest Stream

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Chicory root
Food Application
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Fruit
Cost
Break-even point

Abstract

Sensus produces inulin from chicory root fiber, thereby producing a 40 000-ton rest stream of spent wet chicory root that is currently sold as cattle feed (a low value application). The purpose of this study is to determine a high value food application for this chicory root which contains high fiber content, and create a business case for 10 years with a break-even point of around 4 years to determine whether it is profitable. From the market research of food trends in the Netherlands and EU as well as looking at realistic applications for the chicory root, it is determined that consumers would desire a yoghurt and fruit drink application. From the market volume, process flow diagram, investment costs, production costs, depreciation, and product sale income, it is determined that when the product is sold to the target group in the Netherlands and consumed 2x a week per consumer, selling the product between 0,75 - 0.80 euro/kg (which is the lowest price on the market by 0,20 euros) results in a realistic break-even point of inside 4 years. Product sales in the Netherlands of a yoghurt & fruit drink containing chicory will be profitable inside 4 years, with an annual margin of 792 024 to 2 651 024 euros/year.

Introduction

Sensus, an agricultural company, manufactures inulin from the root of the chicory plant by means of extraction with hot water. 40 million kilograms (40 000 tons) of chicory is processed yearly during its harvest time; September to January, while the extraction of inulin the spent chicory roots remains as the residues (wet matter).

Currently the methods used to handle the spent chicory roots is that to sell it as cattle feed and field fertilizers, however this causes less additional profits to Sensus. One of the options of increasing its value is to produce dried spent chicory roots by means of removing the water from the spent roots, since the dried matter contains a high content of fibers and a small amount of non–extractable inulin and protein. Therefore, the dried matter can be used in food application such as being used as ingredient in i.e. energy bars to increase fiber content, however manufacturing dried matter requires more energy and investment. Therefore, Sensus is looking for the way to increase the value of the wet sliced chicory roots in the field of product development so that the spent chicory root will provide profit for Sensus.

The purposes of this report is to determine a potential high value food application for spent sliced chicory root, design a business case for 10 years for extracted chicory roots with 4 years break–even point. The report demonstrates the followings: the composition of raw material, the health benefits of the chicory roots, market trend and research. In addition, kitchen trials are conducted to design the food product with trial & error, and from that; the process design to create the desired recipe in order estimate the equipment costs, total investment costs, yearly production costs and eventually determine the break-even point.

1. Raw Material (Chicory Waste Stream)

1.1 Composition

Nowadays inulin from chicory extraction is widely used as an ingredient in food application, such as bakery desserts and cereals (Adam Jurgonbski, 2011), since it provides many health benefits. Inulin is polysaccharide which has degree of polymerization (DP) of standard inulin ranges from 2 to 60, usually being manufacturing processed to remove DP fraction to less than 10 before being used in food application (Kalyani Nair, 2010). These inulin act as a prebiotic, proven by the stimulation of the growth of beneficial micro flora and inhibition of pathogenic and putrid bacteria. Besides, they enhance the absorption of minerals from diet for example calcium, magnesium and iron (Joanna Milala, 2009) also help in bowel movement since they cannot be digested by human enzymes. However the residues and the wastes of the chicory is hardly used in industries – normally is used as cattle feed and field fertilizers (Patel, 2012).

In general, inulin can be found in every part of chicory; leaves, roots, and seeds for instance, moreover other components such as protein is highly found in the leaves of chicory compare to the chicory roots (14.7 ± 1.03% in leaves, 4.65 ± 0.25% in chicory roots) However chicory roots contain high level of dietary fiber comparing to chicory leaves which is shown in table 1 below.

Table 1 : Chemical composition of chicory plant *(Mona, 2009)*

Chemical composition %	**Roots**	**Leaves**
Moisture content	75.63 ± 0.39	83.06 ± 1.55
Crude protein	4.65 ± 0.25	14.70 ± 1.03
Crude ether extract	1.69 ± 0.71	3.68 ± 0.19
Ash	4.25 ± 0.11	10.91 ± 1.86
Total carbohydrate	89.41 ± 1.07	70.71 ± 3.08
Total soluble sugar	11.06 ± 1.00	7.80 ± 1.45
Inulin	44.69 ± 0.88	10.95 ± 2.56
Crude fiber	5.12 ± 1.55	16.78 ± 2.20
Dietary fiber (DF)		
- Insoluble DF	30.73 ± 0.33	No Detect
- Soluble DF	0.42 ± 0.07	No Detect
- Total DF	31.15	No Detect

After the inulin is extracted from the chicory, the chicory wastes and residues, which is wet matter is the rest stream. However, this rest stream contains very useful components and minerals such as fibers (cellulose, etc.) approximately 75 – 85%, 7 – 8% protein, and 5% of non–extractable inulin. (Table 2) In addition, the dried spent chicory roots have higher water holding capacity comparing to other fibers (B.M. de Roode, 2015).

Table 2: Comparisons of dried chicory root to other sources (adapted from Chicory Root Fiber From byproduct to food ingredient, 2015)

Source	**Dry matter %**	**Total fiber %**	**Protein %**	**Water holding capacity *(ml/g)***
Wheat	94	93	0.1	3.7
Oat	95	93	0.6	3.1
Soy	90	77	9.7	4.3
Cellulose	94	99	0.1	3.4
Sugar beet	89	63	8.0	3.0
Bamboo	94	48	0.1	4.9
Citric	92	53	8.0	6.5
Potato	89	56	6.0	5.4
Chicory root	93 – 98	75 – 85	7.0 – 8.0	5.0 – 7.2

1.2 Health Benefits

The composition of extracted (spent) chicory root is known:

Table 3: chicory root composition (Roode, 2015)

Spent Chicory Root Composition	%
Dry matter content of roots	25
Composed of:	
Fibers (cellulose, hemicellulose, lignin)	80
Inulin	5
Denatured proteins	10
Ash (mineral components)	5

Chicory root fiber is a dietary fiber. It is indigestible until the large intestine, since the bindings between molecules are not hydrolyzed by human enzymes.
The physiological benefits are as follows:

- Gut microbiota support modulation of gut microbiota by promoting growth of bacteria (Bifidobacterium and Lactobacilli). The prebiotic effect has been observed with a minimum intake of 5g/day and has been observed across the lifespan from infants to the elderly. (Roberfroid, 2010)
- Digestive Health: Improvement of digestive health by supporting normal stool regularity and consistency. Chicory root fiber supports digestive health when 8-12 grams are consumed during various occasions throughout the day. Stool consistency is also influenced positively so that hard stools and painful defecation can be avoided. (Kellow, 2014)
- Weight Management: A proven satiety enhancer, which leads to less total caloric consumption and increased weight loss/maintenance. (see figure 1)

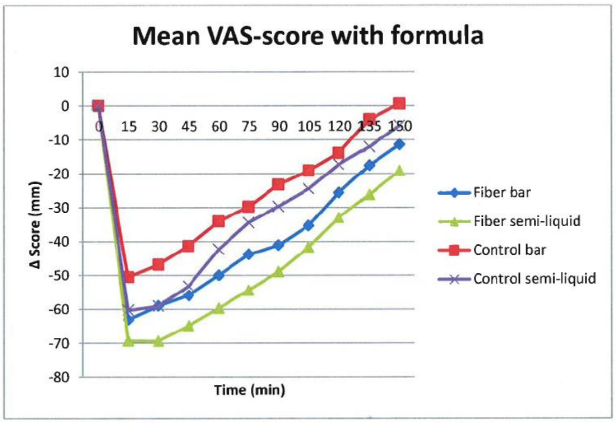

Figure 1: Satiety test with control bars and bars containing chicory root (Roode, 2015)

Figure 1 shows that in an experiment with cereal bars and semi liquid (porridge), the bar and porridge containing chicory root (blue & green) seems to curb hunger more effectively than the control bar (red & purple). Chicory root has a caloric value of 1-1.5 kcal/g, which is lower than other carbs which provide 4 kcal/g. (Roode, 2015)

- Bone health support: Increase of calcium absorption and increase in bone mineral density. This is due to increasing the acidity in the large intestine and increasing the surface area for calcium absorption in the large intestine.
- Blood sugar management: Chicory root has a very low glycemic index, improvement of blood sugar profiles and insulin profiles. Glucose homeostasis, body weight and insulin sensitivity are improved in subjects with pre-diabetes, after 6 weeks of 30g/d intake independent of lifestyle, and compared to cellulose. (Roberfroid, 2010)

In the US, the recommended dietary fiber intake is 14g/1000 kcal. Which means, for an average adult, the daily intake should be 25g for female and 38g for male. Most Americans only consume about half of the recommended intake, the shortage of fiber in a diet is called the fiber gap. Closing the fiber gap could be easily achieved with fiber enriched foods, such as chicory root containing products, however increasing fiber intake suddenly (particularly with people who have low fiber diets), may result in increased negative gastrointestinal effects, and therefore must be consumed gradually. (Roberfroid, 2010)

1.3 Target group

It is very important to consider who the target group is, before making a new food product. There is a preference in having a broad target group due to financial gains. Therefore, it is decided that the target group will be economically active adults from the age of 15 to 64 years' old who are looking for healthy food and on-the-go products. The population of the target group is 65% of the EU according to European Union demographics profile 2016. The target group is very diverse because of their different lifestyles and it will be harder to achieve their essential needs and desires. Thus, our main target group will be adults from the age of 15-64 years in the Netherlands and Europe, who desires or needs to have a healthy food product especially with nutritional benefits from dietary fiber. (mundi, 2016). 65% of the EU population (which is approximately 510 million) amounts to around 332 million people, this seems a bit too ambitious perhaps, so there will primarily be looked at economically active consumers in the Netherlands, which are about 65.7% of 17 million Dutch inhabitants (around 11 million people). (Netherlands Foreign Investment Agency, 2017), however in section 2.5 the market volume of both the Netherlands and the EU will be discussed.

2. Market Research

2.1 Trends

There is a growth in on-the-go meal sector and in-between-meal snacks globally, 2% year-over-year due to the fact that consumers have less time to prepare meals. (Nielson, 2014). The target group of the age between 15 to 64 especially doesn't usually have time to prepare breakfast or lunch. In 2014, it is reported that 28% adults eat four or five mini-meals a day and 21% say that they eat on the run. The majority of consumers would like to have different snacks for breakfast, lunch or dinner and the top five snacks consumption by daypart is shown in Figure 2 (Sloan, 2015), The global snack sales totaled $374 Billion annually and Europe make up one of the majorities in worldwide snack sales with $167 billion. (Nielson, 2014) (see figure 3)

Figure 2: Snack consumption by day (Sloan, 2015)

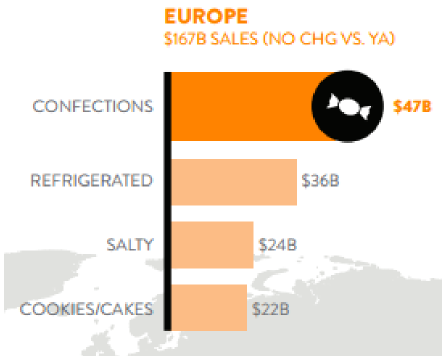

Figure 3: Retail Annual dollar sales ending march 2014

There are several trends among the consumption of snacks. The consumption of confections which includes sugary sweets such as chocolate and hard candy delivers the biggest snack sales of Europe in 2014. In contrast, salty and savory snacks are more popular in North America and Asia-Pacific. It is expected that non-sugary snacks which can replace meals will have a strong growth in the market because the demanding of healthy and convenient snack is increasing each year. (Nielson, 2014)
There are some other important trends in the market as well.

- Interest in organic products and clean labels (Increasing emphasis on absence of artificial colors/flavors, genetically modified organisms and gluten-free as shown Figure 4)
- Focus on food safety (Focus attention on pathogens and prevent food borne diseases)

- Less is more (More demanding of low sugar, salt, fat and calories in manufactured food product as shown in Figure 4)
- Gourmet Convenience
- High quality protein
- Sustainable (Use ingredients which are sustainable, organic and local herbs as shown in figure 4)

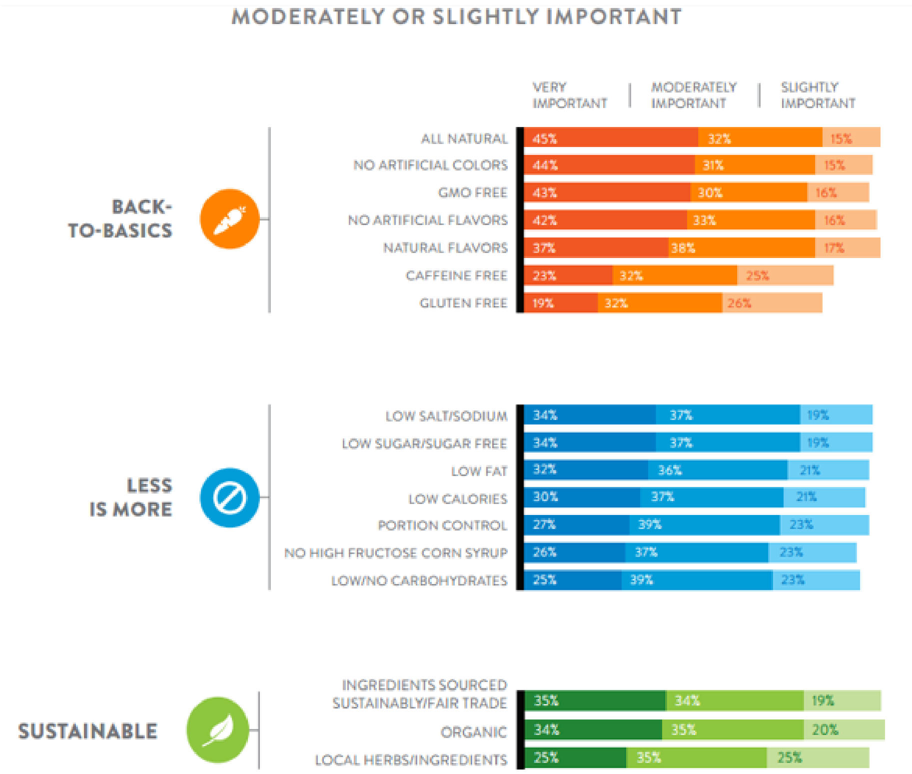

Figure 4: Percentage rating of health attribution (Nielson, 2014)

2.2 Literature (Consumer Survey)

The Nelson Global has polled 30,000 online consumers from different countries and the result showed that the favorite snack globally includes chocolate, fresh fruit, vegetables and cookies etc., shown in Figure 5. In Europe, the favorites include fresh fruit, cheese, yogurt and chocolate as shown in Figure 5 which is very similar to the global result. This research has shown that making a snack based on chocolate or yogurt will guarantee to attract consumers and making profit in the growing market. (Nielson, 2014)

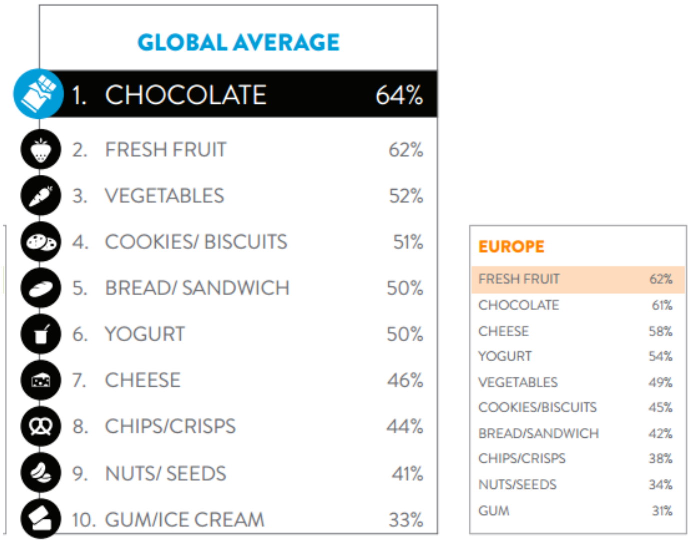

Figure 5: Consumers research on snack (Nielson, 2014)

From the consumer research, context of our raw material (chicory root), and current trends; it is determined that a **natural, gluten free yoghurt & fruit drink containing chicory root fiber** would be the best product for this application.

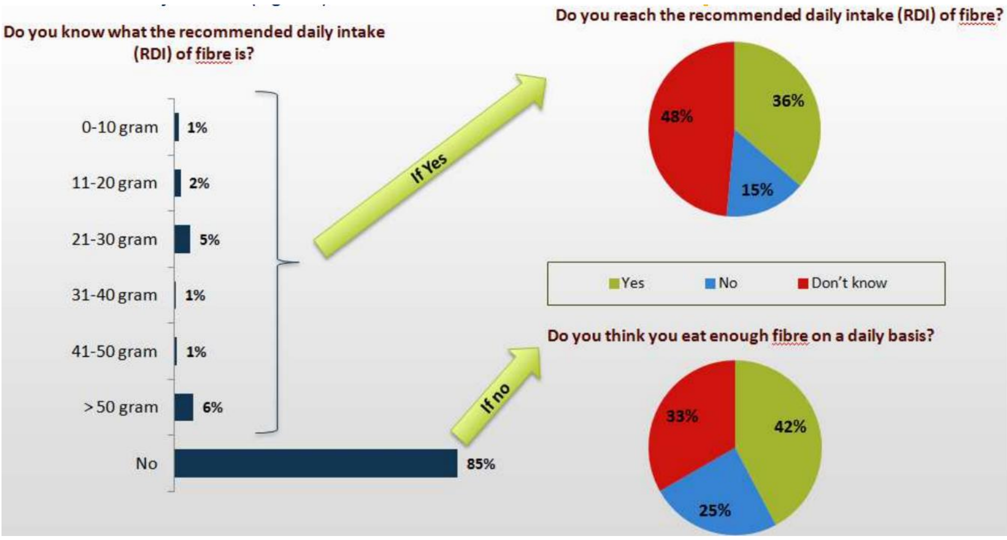

Figure 6: Graph and tables show the percentage of consumers agreeing slightly or entirely with the statement (Sensus, 2016)

From a consumer survey performed by (Sensus, 2016), it revealed that only 13% of those surveyed actively looked for high fiber food products with a further 41% indifferent to the fiber content of their groceries. Those who opted for high fiber products, preferred simpler labelling terminology, whilst 34% chose for a label that identified 'high fiber", 32% opted for a label with the percentage of the recommended daily fiber dosage. (See figure 6). However, those who participated in the survey were given a short introduction to chicory root fiber, and 70% of those surveyed expressed a positive interest in the chicory root fiber when given a short introduction, therefore it is recommended that the possible marketing campaign provides an introduction to the chicory root fiber, and how it would benefit the body. (Sensus, 2016)

2.3 Market Competitors

Looking at products sold in a big supermarket chain in the Netherlands (Albert Heijn), there are a few comparable products on the market. These products (2.3.1) and their nutritional values (2.3.2) are:

2.3.1 Ingredients Drink Yoghurt/Zuiveldrank (Yoghurt drink containing "fruit")

Optimel Drinkyoghurt framboos (raspberry) Price: 1,33eu per 1 L
Nonfat yoghurt, 5% apple fruit juice, 1% of raspberry, aroniaberry & lemon, corn starch, aroma, sucralose (Albert Heijn, 2017)
Vifit Drinkyoghurt rode vruchten (red berries) Price: 1,62eu per 1 L
Yoghurt (0.8%) fat, red fruit juice, and added vitamin B11 & D. (Albert Heijn, 2017)
Fristi rood fruit (red fruit) no sugar: 1,17eu per 1 L
Nonfat yoghurt, whey permeates, 5% fruit juice from concentrate (2.5% grapes, 1.7% apple, 0.8% elderberry, 0.01% strawberry, 0.01% raspberry, 0.01% blackberry, 0.01% cherry), fibres (polydextrose, inulin), stabilizers: pectin, guar gum, aroma, sweeteners: acesulfame-P, saccharin, sucralose, artificial colouring: crimson red. (Albert Heijn, 2017)
Arla biologische milde yoghurt drink zwarte bes & framboos (blackberry & raspberry) Price: 1.39eu per 1 L
Organic nonfat yoghurt, 1% organic cane sugar, organic fruit (0.4% raspberry, 0.3% blackberry, 0.3% black currant), natural aroma, contains: milk protein, lactose. (Albert Heijn, 2017)
Arla Naturals Drink Rood Fruit Price: 1,39eu per 1 L
96.8% nonfat yoghurt, 2% fruit (0.9% strawberry, 0.8% raspberry, 0.3% cranberry), 1% grape juice concentrate, corn starch, natural aroma, lemon juice, sweetener: stevia. (Albert Heijn, 2017)
Campina Yoki Drinkyoghurt framboos Price: 0,99eu per 1 L
Nonfat yoghurt, water, sugar, 1.3% fruit juice (0.7% raspberry, aronia berry, lemon), corn starch, natural aroma (Albert Heijn, 2017)
AH (huismerk) Drink yoghurt Framboos Price: 0,95 per 1 L
79% nonfat yoghurt, whey protein 5%, fruit juice concentrate (1% apple, raspberry, lemon, aronia berry), modified corn starch, E331 aroma, sucralose, vitamin (b2, B6, B12), calcium. (Albert Heijn, 2017)
Vifit Goede Morgen! Breakfast Drink (Strawberry, Kiwi, Banana): Price: 1,59 eu per 1 L
Skim milk, liquid milk compounds, sugar, 1.2% oligo fructose, 1% fruit juice, (0.4% banana, 0.3% kiwi, 0.3% strawberry), corn starch, maltodextrin, 0.4% wheat germ, 0.1% oat bran, calcium lactate, thickener E412, acids, aroma, artificial colouring: crimson red, vitamin B2, B6, B12, folic acid. (Albert Heijn, 2017)
Danone Activia start drinkyoghurt aardbei/kiwi: Price 2,72eu per 1 L
Skim milk, 8.1% sugar, 2.4% strawberry, cream, thickeners (acacia gum, modified corn starch, pectin), 0.6% kiwi, skim milk powder, colouring from carrot and apple concentrate, yoghurt, acid preservatives. (Albert Heijn, 2017)
AH Drinkontbijt perzik/abrikoos: Price: 1,50eu per 1 L
0.8% fat yoghurt, sugar, oligo fructose syrup, fruit juice from concentrate, (0.7% peach, 0.3% apricot), 0.4% wheat germ, 0.2% wheat bran, E331 acid preservatives, calcium lactate, 0.1% oat bran, thickener (guar gum, xanthan gum), aroma, contains lactose and gluten. (Albert Heijn, 2017)

The **Melkunie BREAKER HIGH PROTEIN** (forest berries/banana is not a liquid smoothie type product, but a thicker pouch product), the consistency of which can be obtained by using more chicory root fiber (30%). It has a price of 6,95 euro per kg.
It contains: low fat yoghurt (0,9% fat), whey protein, 8,0% fruit (4% berries, 4% banana), aroma, sucralose.

2.3.2 Nutritional Value Drink Yoghurt/ Zuiveldrank (Yoghurt drink/ Dairy Drink)

Table 4: Nutritional composition of competitor products. (Albert Heijn, 2017)

per 100 mL	Optimel	Fristi	Vifit DY	Arla Org.	Arla Nat.	Campina Y.	AH DY	Vifit GM	Danone Act.	AH DO
Energy (Kcal)	32	31	58	55	30	49	33	64	69	60
Fat (g)	0	0	0,8	0,5	0	0	0,1	0,8	0,9	0,8
Sat. fat (g)	0	0	0,5	0,2	0	0	0,1	0,8	0,5	0,5
Carb. (g)	4,1	4	8,4	9,5	3,9	8,8	5	10,1	11,9	9,5
Sugars (g)	3,6	4	8,1	9,5	3,8	7,8	4,5	8,3	11,7	9
Fiber (g)	0	2,1	0	0	0	0	0	1	0,7	1
Protein (g)	3,1	2,3	3,1	3	2,8	2,6	3	2,9	3	3,5
Salt (g)	0,11	0,12	0,11	0,1	0,09	0,09	0,1	0,11	0,12	0,1

As can be determined from table 4, most of the similar products do not contain any fiber, and the sugar content is quite high. The products that are closest in composition to the desired product containing chicory root are the Vifit GM, Danone Activia, and the AH drinkontbijt. These products contain between 0.7-1 grams of fiber per 100 mL.

The **Melkunie BREAKER HIGH PROTEIN** (forest berries/banana)
Per 100 grams: 54 calories, 0,9 g fat, 0,5 sat. fat, 5 g carbs, 4,5 g sugar, 5,7 g of protein, and 0,11 g of salt. An idea could be to utilize more chicory root to gain a thicker consistency, and by using nonfat (0%) yoghurt and more fruit, and whey protein, the product could have a better overall nutritional value then the Melkunie Breaker, whilst competing in price due to chicory root fiber being free (for the time being).

2.4 Unique Selling Point (USP)

- Dietary fiber content (1 product of 500 mL could be a high percentage of daily recommended value).

Since comparable products on the market do not contain fiber (or very little fiber <2.1 g per 100 mL), a USP could be that the product is a very rich source of dietary fiber. If the product of 500g contains i.e. 20% chicory root fiber, the dietary fiber content would be: 0.20 (20%) * 250 (grams) * 0.25 (25% dry chicory root) * 0.80 (fiber content of dry root) = 10 grams of fiber per drink product of 250 grams. It is determined that the recommended daily intake of fiber should be at least 25 grams per day for ages 11 and over, which means that one product drink has nearly half the entire recommended daily value! Adding inulin as a sweetener will enhance the product fiber content as well. (Sensus, 2016)

- Natural/ clean label

Quite a few of the products in section 2.3.1 contain either or more of; artificial sweeteners, coloring, preservatives and modified corn starch, therefore the product containing chicory root should contain a clean label, with only a select few natural ingredients, such as fruit puree, chicory root fiber, inulin and organic yoghurt.

- Extremely Filling

According to the satiety study by (Roode, 2015) products bars containing chicory root decreases hunger compared to control bars containing conventional carbohydrates, which indicates a more efficient hunger curbing potential than conventional carbohydrates, therefore reducing total daily calorie intake.

2.5 Market Volume

Since the Netherlands contains 11 million economically active consumers (ages 15-64 years), which 13% of this is interested in fiber containing products, it is estimated that 143 000 consumers would buy the product early in the release. Assuming the products will be consumed 4x a week (for breakfast or snack on the go), and that the product will have a weight of 250 grams, it is estimated that **204 tons of product is will be consumed per day in the Netherlands (74 360 tons of product per year).** With the product containing 20% chicory root fiber, it is estimated that **41 tons of raw material (chicory root) is needed per day** if selling to consumers only in the Netherlands, which amounts to **14 872 tons of chicory root needed per year.**

In the European Union there are 332 million economically active consumers, which means that there would be 10,2 million fiber interested consumers which would buy the product. (The World Bank, 2015). The amount of consumers would then result in **a demand of 6 140 tons of product needed per day (2 240 940 tons of product per year),** and therefore **1 228 tons of chicory root needed per day if selling to consumers in the EU, which amounts to 448 188 tons of chicory root needed per year.**

The amount of available chicory root from Sensus is 40 000 tons per year, which means the supply: demand ratio in the Netherlands is around 3:1, and in the EU it is around 1:10. This means that in order to sell in the entirety of the EU, a bulk of additional chicory root will have to be purchased in order to keep up with the demand. It is therefore determined that the market volume will be initially be deduced from inside the Netherlands, in other words; it is recommended to initially (initial 10-year trial period) sell the product in the Netherlands, and when the product becomes successful, to expand production and purchase additional equipment to be able to supply to the rest of the EU. An effective marketing campaign will also ensure a higher percentage of consumers actively looking for products containing fiber due to increased interest after an introduction about chicory root fiber. (Sensus, 2016)

3. Kitchen Trials

To determine how chicory root fiber, affects the desired yoghurt fruit drink product, kitchen trials were performed to create products containing various amounts of yoghurt, fruit, inulin and chicory root fiber.

Table 5: Standard recipe for trial 1.

Trial 1	Recipe	weight in g	%
	Strawberry	60	14,2
	Banana	60	14,2
	Yoghurt 3%	300	14,2
	Inulin	3	7
	Total	423	100

- The ingredients are **blended** together with a blender until homogenous.
- The wet chicory root is **sterilized** and **washed** to kill pathogenic bacteria and remove excess dirt (may also be pasteurized).
- The recipe is divided into 3, after which different percentages (5,10,20%) of wet chicory root is added to the mixture, and **blended** again until homogenous

Table 6: Effect of chicory root concentration on sensory characteristics trial 1.

Chicory %	Taste	Texture/color	Smell
5	no chicory taste, not sweet	quite thin/liquid, pink	No chicory smell
10	no chicory taste, not sweet	still thinner than average smoothie, fibers present, chewy, pink	No chicory smell
20	no chicory taste, not sweet	thicker than smoothie, fibers present, chewy, pink	no chicory smell

Further comments: The recipes were not sweet enough, adding more sweetener such as honey, sucralose, inulin or sweet tasting fruit is recommended. Adding more fruit could also make the recipe taste less fibrous/chewy. The samples did not have a chicory taste/smell. The strawberries gave the product a pink color, however the high water content in strawberries may affect the overall texture negatively (by not affecting the chewiness/ fibrous nature such as banana can). (Bastin, 2011)

Table 7: Standard recipe for trial 2.

Trial 2	Recipe	weight in g	%	Comments:
	Banana	327	54,5	No strawberry available
	Yoghurt (0.5 %)	240	40	
	Inulin (frutalose L85)	21	3,5	sweet enough
	Total	588	100	

In the 2nd kitchen trials, the base method of blending to a homogenous mixture and sterilizing the wet chicory root was used, strawberry was not available this day, therefore 50% banana was added which gave the recipe a rich banana taste. The amount of inulin used at 3.5% ensured a desired sweet taste, further masking the bland taste of chicory. This recipe was again divided into 3, and different percentages of chicory root added (10, 20, 50%). 0.5% fat yoghurt is used instead to reduce calorie content of the smoothie.

Table 8: Effect of chicory root concentration on sensory characteristics trial 2.

Chicory %	Taste	Texture/color	Smell
10	no chicory taste, sweet	Smoothie texture, less fibrous and chewy than trial 1, bland color	no chicory smell
20	no chicory taste, sweet	Thick texture, less fibrous and chewy than trial 1, bland color	no chicory smell
50	no chicory taste, sweet	Very thick, less fibrous and chewy than trial 1, bland color	no chicory smell

Again, no chicory root taste and smell were perceived in these samples. This could be due to the high ester & sugar content & of the ripe bananas used. The banana also seems to reduce the fibrous and chewy nature of the chicory, if it is blended into a homogenous mixture. However, without any fruit with significant pigmentation, the product seems to have a bland and undesirable grey color. It is therefore recommended that fruit with high anthocyanins pigmentation be added (such as strawberries, blueberries, raspberries, blackberries) (Douma, 2008) to mask the bland color of chicory, as well as fruit with a relatively lower water content (comparing with other) fruits as well as a high ester content (such as banana, pears, apple, grapes) to mask the bland taste and fibrous texture of chicory. The thickness of the smoothie at 20% is similar to various smoothies on the market, however the thickness at 50% seems too thick to drink normally, but an idea could be for the product to be “pushed” it out of a pouch like the “Breaker” product from Melkunie.

Recommendations for future trials: Use 30% ripe banana, 7% fruit containing high percentage of anthocyanins, 20% chicory root, 3% inulin and 40% nonfat yoghurt. This will ensure a healthy and filling low calorie product with high dietary fiber content and high amount of antioxidants. The high content of banana will ensure a less fibrous tasting product, and 6% of a high anthocyanin content fruit will be able to give the product a desired bright color, and both these fruits would also mask the taste of chicory root. Using a relatively high percentage of chicory root would keep the product price competitive as well as being able to sell off a large volume of wet chicory root product for this application. Blending the wet chicory root with the other ingredients to a small particle size into a homogenous mixture seems to mask the fibrous texture of the chicory well enough to be more than palatable.

4. Processing Food Product

4.1 Process Description

Yoghurt is a primary ingredient for the yoghurt & fruit drink product. In this business case, it is assumed that the yoghurt will be produced on-site. There are many types of yogurts and each type has its specialty for example Greek yogurt, set yogurt and stirred yogurt. Set yogurt is formed by pouring milk in container then incubated without any further stirring. While stirred yogurt is from the set yogurt is stirred into a creamy like yogurt, fruits or other flavorings are usually added to this type of yogurt. The processes of yoghurt production are most likely the same, only some steps are applied such as the milk is skimmed before being used in low fat yogurt, it is assumed that low to non-fat yoghurt will be used in this product. The following are the main process steps in the production of our product.

4.1.1 Pre - Heating

Fresh milk is heated to 60 – 65^{o} Celsius because the fat needs to be in liquid state before homogenization. If the fat in the milk is not in liquid phase it could cause separation of fat layer during incubation and at later stages of storage and transportation. Yet in could affect to the color of the product since the fat globules affect to the light reflectance and scattering. Hot water is used to heat the milk during the step of preheating (60 degrees Celsius) since the heated water will be reused in the step of pasteurization (90 degrees Celsius), this will optimize energy during heating water. In addition, hot water leaving pasteurizer could be used in the step of chicory root treating because the chicory root needed to be cleaned to prevent physical, chemical, and microbiological hazards that can occur. The process flow diagram of yogurt is shown below.

4.1.2 Homogenization

In this step the pre – heated milk is homogenized (150 bar) to reduce the size of the fat globules to an average of 2 microns in diameter from the normal size which is 1 – 20 microns. This is to prevent the separation of fat in the final product.

4.1.3 Heat Treatment (Pasteurization)

To eliminate undesired microorganisms the milk is heated up to 85 degree Celsius for 30 minutes or 95 degree Celsius for 10 minutes (Milk Facts, n.d.). In addition, the texture of the product is improved and whey separation during storage time is prevented due to the denaturation of whey proteins.

4.1.4 Cooling and Fermentation

The milk is cooled down to suitable temperature, which is approximately 43 - 46 degree Celsius, before inoculation then starter culture is added (2%) (Background, n.d.). After the pH of the milk reaches 4.4 the curd begins to form. Incubation time is around 5 – 8 hours.

4.1.5 Mixing

After the chicory root is sterilized and washed in boiling water and ground into the right particle size, the chicory root is added to the fermented yoghurt with other ingredients such as fruit purees and inulin.

4.1.6 Packaging

Depends on type of yogurt, e.g. set yogurt is packed before fermentation. For stirred type yogurt, after incubation the gel (curd) is broke by means of stirring before packing. After that the product is kept cool.

4.1.7 Storage

The product should be kept in shill storage (2 – 5 degree Celsius, with no rise above 10 degrees Celsius) to stop fermentation process.

4.2 PFD

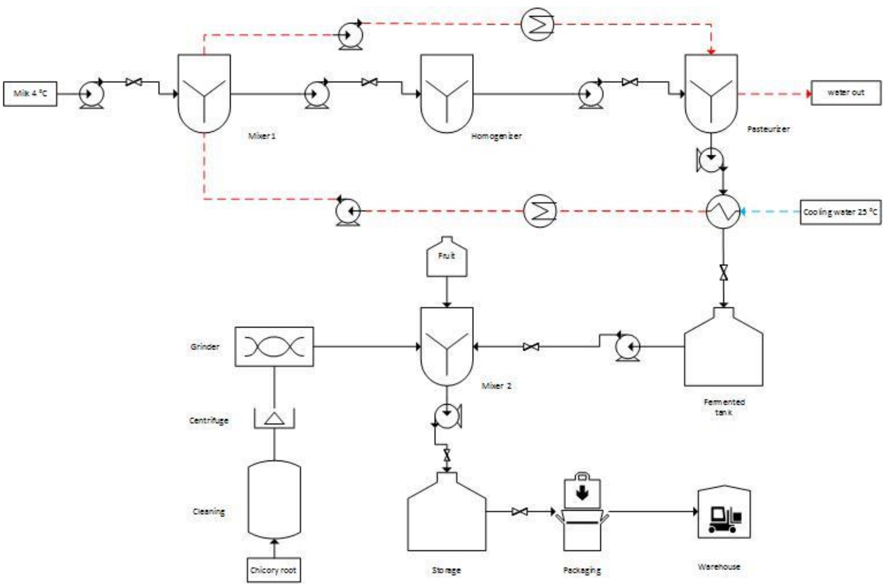

Figure 7: PFD of Chicory Root Fruit & Yoghurt Drink product

4.2 Equipment Needed

The equipment needed is derived from the PFD (see figure 7).
For the production of yoghurt

- 7 Pumps
- Boiler
- 3 Mixing Tanks (low shear) (vertical Tank with propeller)
- Heat Exchanger (Shell & Tube HE)
- Fermenter (Reactor)

For the processing of the spent chicory root raw material:

- Washer/ boiling tank (Vertical Tank & Boiler)
- Press (Centrifuge)
- Pulveriser

In order to mix (high shear) the yoghurt, chicory, fruit and inulin:

- Mixing tank (vertical tank with propeller)
- Pump

Product packaging:

- Storage/buffer Tank
- Conveyer belt

After which the product is bottled, stored under cool conditions and shipped by truck out daily to the domestic supermarkets. The equipment will be made from stainless steel to limit/prevent fouling due to the food materials from occurring.

5. Health and Safety

5.1 Sustainability & Environment

Food industries have an increasingly important role on the environment, because they are the one largest sources of environmental impact when compared to other industries. Due to this reason, many countries around the world, especially in Europe, try to find new ways to reduce inputs, optimize food production process and minimize waste. The consumer's interest in sustainability is growing each year and recent trends on sustainability in food production have also been increasing. Therefore, it is significant to look into the desired food product in terms of sustainability. Firstly, using chicory roots obtained from a rest stream as an ingredient for making a new product aims mainly toward sustainability. Moreover, there are only two main ingredients used in the production (yoghurt and fresh fruits) which can also reduce the negative impact on environment since using minimal raw materials is one of the key to be more sustainable. However, dairy production has been largely responsible for its large carbon footprint because of the natural methane production form cows and manures as well as transportation and processing of the milk. Therefore, it is very crucial to find source with less intensive feeding and raising the animals to comply with the sustainability's principle. (European, 2016) (Baldwin, 2010) It is also important to ensure that the fruit obtained is from a source where high bio-diversities are a priority.
The heat duties and power needed are also relatively small for processing the desired product since boiling of the chicory roots and pasteurization of milk only last approximately 10 to 15 minutes at 95-100°C, as well as cold storage (at 4º Celsius), and the rest of the steps are simply mixing. The package of the product needs to be sustainable as well, due to the fact that production and disposal of packaging has large effect on the environment. For this reason, the package should be biodegradable and come with minimum surface area of packaging where reducing total energy required to produce new packaging. It can be said that making of the desired product is quite sustainable due to minimal different raw materials, and which are organic and promote health and wellbeing for consumers and producers alike. In addition, the food waste is reduced drastically by reusing the chicory rest stream, which is a key practice in sustainability.

5.2 HACCP

The HACCP table provides all the hazards that can be associated during processing yogurt product and the necessary measures to control the hazards. The pasteurization process is crucial since this step eliminates the pathogens and other undesirable micro-organisms. It is also important to remove all the foreign materials because it can have negative effect on the appearance of the final product. Homogenization and fermentation steps will also have impact on the physical characteristic and sensory properties of the end product.

The "process steps" column presents the steps used in making the product. The "hazards" column identifies the type of hazards that is expected in the processing steps where "B" stands for Biological hazard, "C" stands for chemical hazard and "P" stands for physical hazard. The "control measures" column provides information about how the process is controlled to minimize the hazards. The "critical limits" column presents the critical limits for each process steps and "corrective actions" column shows procedures to follow when a deviation occurs.

Process steps	Hazards	Potential Hazards	Control measures	Critical limits	Corrective actions
Raw Milk (Receive Milk)	B	Presence of micro-organisms	Microbiological analysis, Keep records for each tanker	Below the pathogens limits	Minimize the incoming bacterial load by purchasing Grade "A" IMS listed raw milk.
Storage (Cooling Milk)	B	Microbial	Temperature	Cooled to <3°C	Maintenance of the cooler
Stirring and heating milk	B	Presence of pathogens due to improper cleaning equipment	Cleaning	Within parameters	Equipment sanitizing and inspection regularly. Training Cleaning procedure SOP
Homogenization	B	Microbial	Cleaning	Within parameters	Equipment sanitizing and inspection regularly. Training Cleaning procedure SOP
Pasteurization	B	Survival of pathogens	Temperature and time recorder on visual display	>90°C <95°C	Re-Pasteurize
Product culturing	B	Growth of pathogens and development of toxins	Protect the environmental conditions around the vats from contamination	Within parameters	Enclosing or covering the vats during set. Implement a procedure that will eliminate the possibility that cultured products containing toxins are distributed.
Cooling down and ferment in the tank	B	Microbial	Monitoring temperature on visual display	>40°C <45°C	Too high : can be cooled with ice water too low: stop the process
Boiling Chicory root	B	Survival of pathogenic microorganisms	Monitoring the temperature and time on visual display	>100°C From 10-15 minutes	Re-boiling if the temperature is too low.
Filtering Chicory root	P	Foreign matter	Audit /Visual Inspection	Within parameters	On line filter plus maintenance
Grinding Chicory root	P	Contamination by metal fragments due to equipment and utensil wear and tear	Audit /Visual Inspection	Undamaged	Monitor equipment set-up and wear through an effective preventive maintenance program. Inspect equipment and utensils regularly.
Metal detection	P	Ineffective detection by the detector	Monitor and control the function of metal detector	Within parameters	Regularly calibrate metal detector and maintenance.
Addition of fruits	B P	Presence of pathogen Foreign matter	Microbiological analysis, Keep records. Audit /Visual Inspection	Below the pathogen limits.	Supplier guarantees. Checks on supplier.
Storage the product	B	Microbial	Controlling the temperature	<4 ºC 24h	Locate thermometers and monitored to be sure that the coolers will hold product below the bacterial growth range.
Packaging	C B	Chemical residues in packaging materials Pathogens contamination	Cleaning and sanitizing	Wash 24 h before	Personnel hygiene Cleaning program Supplier guarantees for packaging material
Dispatch	B	Growth of pathogenic microorganisms due to time or temperature abuse during dispatch	Monitoring the temperature	<4 ºC	Transport product in a timely manner at a temperature that will minimize the growth of pathogenic microorganisms.

Table 9: Hazard Analysis (FDA, 2006) (MPI, 1981) (Hoolasi, 2005)

6. Cost and Profit

6.1 Major Equipment Items Cost (PCE)

Table 10: Equipment list and corresponding costs using the method in (Sinnot, 2005)

Process	Equipment	Parts	Size	Unit	Cost Cons. (euro)	Index	Material	Equipment Cost (euro)	Comment
Yoghurt production	7 Pumps								Pumping milk
	Boiler		1687	kg/h	89	0,77		27268	Heats from 4 to 65 Celsius
	Mixing Tank	Vertical Tank	20	m3	2143	0,6	SS	12930	Mixer 1
		Propeller	35	kW	1696	0,5	SS	10036	Mid shear
	Mixing Tank	Vertical Tank	20	m3	2143	0,6	SS	12930	Homogenizer
		Propeller	75	kW	1696	0,5	SS	14692	High shear
	Mixing Tank	Vertical Tank	20	m3	2143	0,6	SS	12930	Pasteurizer
		Propeller	5	kW	1696	0,5	SS	3793	Low shear
	Heat Exchanger*	S&T HE	20	m2			SS	20000	Cooling milk to 42 Celsius with water
	Fermenter	Reactor	20	m3	27679	0,45	SS	106563	Milk fermented into yoghurt
Chicory Root fibre processing	Washer/boiling tank	Vertical Tank	15	m3	2143	0,6	SS	10880	Chicory root washed & boiled
		Boiler	1478	kg/h	89	0,77		24628	Heats up to 100 Celsius
	Press/centrifuge *	Horizontal basket	0,75	dia. m	51786	1,7	SS	31755	Water removed from chicory
	Pulveriser	Grinding tool	1700	kg/h	3036	0,35	SS	41013	Chicory pulverized to low particle size
Ingredient mixing (into product)	Mixing Tank	Vertical Tank	60	m3	2143	0,6	SS	24997	Yoghurt mixed with chicory & fruit puree
		Propeller	75	kW	1696	0,5	SS	14692	High shear mixing
	Storage Tank	Cone roof	60	m3	2054	0,55	SS	19521	Storage/buffer tank
	Pump								Pumping viscous product
Product packaging	Packaging	Conveyer belt	10	m	1696	0,75	SS	9540	Packaged into cartons/bottles
Total (CS)								398169	euros
Total (SS)								776338	euros
	* means estimate	4 batches a day	1 kg = 1 L						

It is determined that the production will be split into 4 batches a day to limit sizing (assuming a fermenting time of 5 hours). Assuming that 1 kg of the streams are 1 L, and that the material used is stainless steel (SS) in order to prevent fouling:
The specific equipment and their individual costs can be found in table 9.

The tanks containing milk and eventually yoghurt are sized at 15,3 m^3, rounded off to 20 m^3. The power of agitators in the tanks are assumed to produce a low, mid and high shear, and adjusted accordingly. The boiler steam needed to heat up the milk is calculated using Q= m* C_p * delta T, with the parameters: the heat capacity of milk, mass, temperature difference and the latent heat of steam. The steam needed= Q/latent heat of steam, which amounts to 1687 kg/h of steam needed to pasteurize the milk.

The S&T heat exchanger to cool the milk down from 90 to 42 degrees Celsius, and assumed to have a heat transfer surface area of 20 m^3. The chicory root is estimated to need 10,2 m^3 tank capacities, which is rounded to 15 m^3 to allow room for variability. The boiler to sterilize the chicory is calculated the same way as written above, however this time the heat capacity of water is needed, the mass of chicory root needed, as well a delta T of 75 degrees Celsius. The steam needed for this boiler is then calculated at 1478 kg/h of steam needed to sterilize the chicory root. The centrifuge is estimated to have a diameter of 0,75 m. The grinder has a capacity of 1700 kg/h, which is the hourly mass of processed chicory root fiber. The mixing tank to mix the yoghurt, chicory root, and fruit puree, is estimated to contain a high shear rate capacity, and is calculated to need a 51 m^3 tank, which is rounded off to 60 m^3 to avoid overfilling. The storage tank has a capacity of 6 hours of product (1 batch) and needs to be emptied when the new batch production begins. The conveyer belt used to package the product is estimated at 10 m long, however the length of this has little effect on the equipment costs. The pumps are calculated factorially as part of the total utilities.

The individual prices of the equipment are estimated by this equation:
PCE= Costs Constant * Size ^{index}
The cost constants, and indexes can be found in table 6.1 in (Sinnot, 2005).
After which the individual costs are added in order to gain the price for carbon steel material. To get the price for the same equipment in stainless steel, the price is doubled in order to get a total equipment price of 776 338 euro.

6.2 Total Investment Required

Table 11: Estimation of fixed capital costs using the factorial method in (Sinnot, 2005)

PCE =	776338	Euros
	Factor	Cost
Equipment erection	0,45	349352
Piping	0,45	349352
Instrumentation	0,15	116451
Electrical	0,1	77634
Buildings, process	0,1	77634
Total PPC	1746760	euros
Design and Engineering	0,25	436690
Contractor's fee	0,05	87338
Contingency	0,1	174676
Fixed Capital	2445464	euros

Assuming a fluid-solid process the total physical plant (PPC) costs is estimated at 1 746 760 euro, using the factorial method in (Sinnot, 2005). The fixed capital costs are calculated by summing the direct and indirect costs from the PPC using the factorial method and amounts to 2 445 464 euros. The working capital is estimated to be about 10 to 20 percent of the fixed capital. For this business case, a percentage of 15 is taken and this results in a working capital of 489 092 euros. The working capital and the fixed capital are added in order to get a total investment of 2 934 556 euros.

6.3 Variable Costs

6.3.1 Cost of Ingredients

The cost of possible ingredients is:
Banana puree: 0,675eu per kg (International Trade Centre, 2014)

These high anthocyanin containing berries can be obtained from SVZ (an affiliate of Sensus), the prices are obtained from the company.
Strawberry puree: 1,15eu per kg
Blackberry puree: 0,85eu per kg
Raspberry puree: 1,75eu per kg
Price of Inulin (will be provided by Sensus): 1,80eu per kg (Sensus, 2016)
Bulk price of organic skim milk: 0.555eu per L (Raeijmaeckers, 2015)
Bulk price of organic yoghurt is 2,79 euro per kg. (General Mills Convenience & Foodservice, 2017)
Using the recipe for a yoghurt smoothie drink type product:
30% ripe banana, 7% fruit containing high percentage of anthocyanins, 20% chicory root, 3% inulin and 40% nonfat yoghurt.
The demand of the product is estimated at **74 360 tons of product per year = 74,36 million kg per year**
The price of product of the additional ingredients per year will be:
Banana = 15,01 million euros per year
Blackberry (cheapest) = 4,42 million euros per year
Inulin = 4,015 million euros per year
Milk (assume yoghurt yield is 100%, and 1 kg milk is 1L): = 16,508 million euros per year.
Total price of additional ingredients = 39,953 million euros a year.

6.3.2 Misc. Production Costs

The pumping costs are assumed to be negligible
This is only an estimate for the sake of simplicity, and due to factors such as reduced pump efficiency and pressure drop, the pumping power needed will likely be high.
Due to this plant being an extension of Sensus inulin production plant, the Heat Exchanger Network may be optimized in order to make use of efficient heat loops to reduce the cost of utilities, but this will not be discussed in this article. The prices of steam, cooling and process water, and effluent treatment are also not taken into account in this article. Table 6.5 in (Sinnot, 2005) may be used to give a more accurate estimation of utilities.

Table 12: Production Costs, method obtained from table 6.6 in (Sinnot, 2005)

Variable Costs A	Variable Costs	Euros / year
1	Raw Materials	39530000
2	Misc. materials	18341
3	Utilities	Negligible
4	Shipping and packaging	Negligible
	Sub Total A	39548341
Fixed Costs B	*assuming 2 operators and 1 chemical engineer	
5	Maintenance	183410
6	Operating labour*	161000
7	Laboratory costs	32200
8	Supervision	32200
9	Plant overheads	80500
10	Capital Charges	244546
11	Insurance	24455
12	Local Taxes	48909
13	Royalties	24455
	Sub Total B	831675

	Direct production costs A+B	40380016
C 14	Sales Expense	4038002
15	General Overheads	4038002
16	R&D	4038002
	Sub Total C	12114005
	Annual Production Cost A+B+C	**52494020**

The annual production costs are obtained using the method in table 6.6 in (Sinnot, 2005). The variable costs depend mostly from the cost of the raw materials. The fixed costs are obtained as a percentage of the fixed capital costs. The operating labor costs are estimated from average salaries for 2 process operators (48k euros a year), and 1 process engineer (65k euros a year).

The plant is just an extension of the Inulin production plant from Sensus and fully automated, which indicates a lesser need for manual labor. Numbers 7 through 9 are (20, 20, 50 percent) percentages of the labor costs. The direct production costs are an addition of subtotal A and B, and the annual production cost is the sum of subtotals A, B, and C, which amounts to around 52,5 million euros per year.

6.4 Product Selling Price

Looking at the prices of the competitors in section 2.3.1 and assuming the density of the products are the same as water. It can be determined that our product should be sold at lower than 0.95 euro per kg. For the first estimate we shall assume that our cheapest product will cost 0,725 euro per kg (0,725 euro per L) for the smoothie/yoghurt drink type product in order to be more than competitive with similar competitor products.

6.5 Break-even point

Table 13: Cumulative cash flows for different usage frequencies and prices

	4x a week	4x a week	2x a week	2x a week	2x a week
	(0,725 eu/kg	0,80 eu/kg	0,725eu/kg	0,75 eu/kg	0,80 eu/kg
Time (years)	Cash flow (euro)	Cash Flow (euro)	Cash Flow (euro)	Cash Flow (euro)	Cash Flow (euro)
0*	-€1.517.576,00	€3.765.968,40	-€3.072.031,60	-€2.142.531,60	-€283.531,60
1	-€394.051,60	€10.466.492,80	-€3.209.507,20	-€1.350.507,20	€2.367.492,80
2	€729.472,80	€17.167.017,20	-€3.346.982,80	-€558.482,80	€5.018.517,20
3	€1.852.997,20	€23.867.541,60	-€3.484.458,40	€233.541,60	€7.669.541,60
4	€2.976.521,60	€30.568.066,00	-€3.621.934,00	€1.025.566,00	€10.320.566,00
5	€4.100.046,00	€37.268.590,40	-€3.759.409,60	€1.817.590,40	€12.971.590,40
6	€5.223.570,40	€43.969.114,80	-€3.896.885,20	€2.609.614,80	€15.622.614,80
7	€6.347.094,80	€50.669.639,20	-€4.034.360,80	€3.401.639,20	€18.273.639,20
8	€7.470.619,20	€57.370.163,60	-€4.171.836,40	€4.193.663,60	€20.924.663,60
9	€8.594.143,60	€64.070.688,00	-€4.309.312,00	€4.985.688,00	€23.575.688,00
10	€9.717.668,00	€70.771.212,40	-€4.446.787,60	€5.777.712,40	€26.226.712,40

The cumulative cash flow is determined from the total investment cost, total production costs, depreciation (estimated at 10% per year = 293 456 euros per year), and annual income from product sales.
It is assumed that production and sale start immediately (year 0). The annual income from product sales are 53 911 000 euros when selling at 0,725eu per kg, whilst selling at 0.80eu/kg will result in an annual

income of 59 488 000 euros, when the market volume is 74 360 000 kg per year (4x consumption per week per person).

This results in a break-even point in the 2nd year for 4x a week, 0,725 euro/kg, with a margin of around 1,12 million euros a year.
When selling the product at 0,80 euro/kg, the break-even point is immediately, which indicates an overly ambitious estimation, with a margin of more than 6,7 million euros a year. (See table 12)

It could be that the market volume is too ambitious and high unlikely for consumers to consume the product 4x a week, and therefore will be estimated now at 2x consumption per week. The market volume is halved to 37,2 million kg per year, however it is assumed that the total investment cost will stay the same, in order to be able to keep up with future demand when the product is successful.
The annual income from product sales are 26 955 500 euros when selling at 0,725eu per kg (2x a week consumption), whereas selling at 0.80eu/kg will result in an annual income of 29 744 000 euros. The production cost is 26,8 million euros per year, and the depreciation of 10% stays the same.

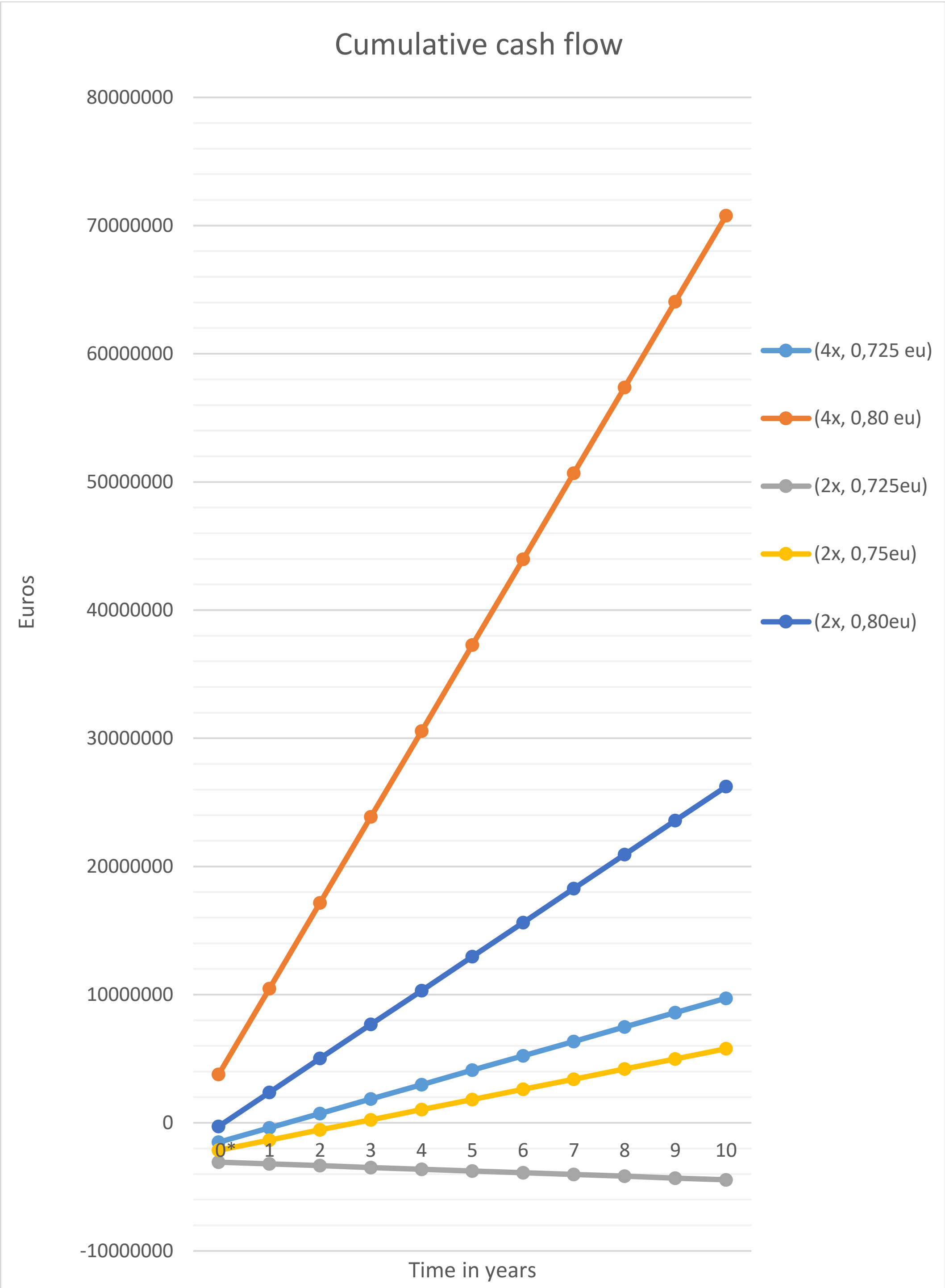

Figure 8: Cumulative cash flow for different market volumes and product prices.

This results in no break-even point when selling at 0,725 euro/kg, with the plant even sustaining a loss when including the depreciation. The result for selling at 0,75 euro/kg (2x consumption per week), is a break-even point in the beginning of the 4th year of production, with a margin of 792 024 euros/year. The break-even point when selling the product at 0,80 euro/kg is in the 1st year, with a margin of 2 651 024 euros/year. These results are found in table 12 and figure 8.

7 Conclusion

A business case for a possible high value food application for the chicory rest stream needed to be created, with a break-even point of maximum 4 years. From the market research it is determined that recent trends of consumers in Europe prefer a yoghurt (50%) & fruit (62%) application product. 13% actively look for high fiber products, however when introduced to chicory root fiber, 70% of consumers displayed an interest in it. From the market demand is determined that a yoghurt & fruit drink containing chicory root would be the desired product for the European/Dutch market. The USP of this product over its competitors is its extraordinary dietary fiber content, its clean label, and its hunger curbing capabilities. When the product is sold to the target group in the Netherlands and consumed 2x a week per consumer, it is determined that selling the product between 0,75 - 0.80 euro/kg (which is the lowest price on the market) results in a realistic break-even point of inside 4 years.
In conclusion, when selling in the Netherlands, a yoghurt & fruit drink containing chicory will be profitable inside 4 years, with an annual margin of 792 024 up to 2 651 024 euros/year.

8 Discussion

The market volume is derived from the demand for the product, however it is not yet fully clear what the effect of marketing will have on the demand for the product, or how many times consumers will consume the product per week. The equipment list is estimated very simply, with the result of the equipment costs seeming on the low side. Some equipment such as the S&H heat exchanger, centrifuge and the conveyer belt are all based on very loose estimates, however it is clear that compared to the raw materials, the total investment costs would still be relatively low and therefore it seems that these pieces of equipment may not have a big effect on the eventual business case. The assumption that 1 kg of raw material or product is equal to 1 L also may affect the business case, due to resulting inaccurate equipment sizing, however a higher density would result in a lower volume of the reactors, which would mean less SS needed and the price lowered. The assumption that the yield yoghurt from milk is a 100% will affect the business case in that more milk is needed to create the same demand for yoghurt, therefore needing to increase the reactor sizes for yoghurt production. The utility costs are neglected in this business case, which would of course be far higher in the pasteurization and sterilization process for both milk and chicory root. It is assumed that the chicory root fiber will cool during the 2nd washing and grinding steps, and therefore no additional cooling step is needed to cool the roots. The pumping calculations also don’t take into account the high viscosities of the yoghurt and product, and is therefore estimated to be much higher than initially calculated. Furthermore the entire business case is estimated with the method from (Sinnot, 2005), this may have a big impact on the business case, as some profit margins are relatively low, which would result in a possible loss, however, this is a preliminary estimate, and the selling price of the product is relatively low compared to the average of competitors products, which means that the profit also has room to improve greatly. The fact that chicory root remains a no/low cost raw material could change when the product becomes successful and the demand for it increases, therefore driving up the price of the eventual application products. The prices of the berries vary greatly, i.e. raspberries cost 2x as much as blackberries, and will affect the break-even point. The assumption that the sale starts at year 0 is also too ambitious, therefore a better assumption of between year 1 and 2 would result in more accurate break-even point. More importantly, it is the purpose of Sensus to present the product idea and business case to other companies, in order sell processed chicory root fiber to those manufacturers that could produce the chicory yoghurt & fruit drink product, and therefore only the chicory root processing is needed for the business case, reducing the investment costs even further, due to the yoghurt production, and mixing not being necessary.

9 Recommendations

Due to time constraints these recommendations are given to continue with the work:

- Create business case, taking only the processing of the wet chicory root (washing, boiling, cooling, storage) into consideration.

- Analyze the microbiological activity of wet chicory root and determine the suitable method of pasteurization or sterilization, as well as cooling in storage to avoid pathogenic microorganisms.
- Perform further and official (with tasting panels) kitchen trials with fixed and variable parameters to determine the correct recipe to Sensus' standards (& style) by optimizing: mixing time to attain an optimal particle size that affects consistency, effect of various types and quantities of fruit on sensory characteristics.
- Explore various recipes which would give greater certain nutritional benefits per product (High protein, energy, "detox").
- Make a list of nutritional facts of the recipe for the chosen product, and change the ingredients and parameters to vindicate the possible USP's.
- Make detailed PFD, energy balances, and mass balances, HEN optimization calculations, derived from production process (of chicory root only) to make a more accurate estimation of costs, and take correct density of the fluids into account.
- Research various marketing techniques for the product in order to increase demand for high fiber products.
- Create additional break-even points for the other more expensive berries (i.e. raspberries, strawberries) and evaluate the impact on the business case (such as affecting the price of the product), this counts as well for other additional raw materials.

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