Investigation of possible quality deviations & critical quality points in packaged beverages with bio-based materials

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1 Introduction

1.1 Background

1.1.1 Food packaging and the current conditions

EU Directive (1994) through Packaging and Packaging Waste Directive 94/62/EC defined packaging as “any material of any nature that is used for the containment, protection, handling, delivery, and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer.” Concerning food, the packaging is closely related to daily life as much as food, since a person typically consumes food three times a day (Marsh and Bugusu, 2007). In general, food packaging is necessary to protect food from potential damage and unintended conditions, to contain food, and to inform consumers about nutritional values, ingredients, as well as the best-before date (Iacovidou and Gerassimidou, 2018; Marsh and Bugusu, 2007; Petersen *et al.*, 1999). Lately, it is found that food packaging also helps companies and consumers to improve convenience and traceability of the food products along with to reduce the risk of fraud (Robertson, 2018; Marsh and Bugusu, 2007).

Among all food packaging materials used globally, plastic is indeed most widely used (Yadav, Mangaraj, Singh, and Simran, 2018; Peelman, Ragaert, Verguldt, Devlieghere, De Meulenaer, 2016; Molenveld, Van den Oever, and Bos, 2015) either for single use or in combination with other materials, considering its flexibility, resistance to various conditions, less breakable and lightweight characteristics (Clark, 2018; Iacovidou and Gerassimidou, 2018; Marsh and Bugusu, 2007). Consequently, plastic production rises every year (Putranda, 2017). It is in line with the evidence revealing the manufacture of plastic worldwide nearly increased up to 350 million tonnes in 2017 (PlasticsEurope, 2018). On the other hand, plastic contributes to large quantities of total municipal solid waste (Singh and Sharma, 2016). Since it is hard to degrade (Iacovidou and Gerassimidou, 2018; Molenveld *et al.*, 2015), plastic is predicted to stay permanently in landfills damaging the ecosystem (Clark, 2018). Another issue regarding plastic used for packaging is the feedstock used to manufacture plastic, petroleum, is one of the non-renewable sources (Clark, 2018; Molenveld *et al.*, 2015).

1.1.2 Sustainable packaging

In supporting circular economy and minimizing the harmful effects of plastics in the use of food packaging materials, alternative actions, including modifying packaging materials, are gradually taken into account (Ramos, Valdez, and Garrigos, 2016). In the Netherlands, for example, the packaging industries and central government, together with municipalities, are committed to implementing ‘Packaging Framework Agreement’, which focuses on recycling, reuse, and collection of packaging materials from 2012-2022 (Molenveld *et al.*, 2015).

Besides recycling and reuse, there are other new sustainable materials, also called bio-packaging, which are now considered to be adopted by packaging and food industries. Molenveld *et al.* (2015) indicated that the term ‘sustainable packaging’ also covers packaging materials reduction and materials, which have positive impacts on the environment. The impacts can be (1) suppressing the use of non-renewable resources and (2) lowering CO_2 emissions (for bio-based material); and (3) accelerating the degradation process of waste (for compostable material).

1.1.3 Selection of packaging material

Even though bio-packaging seems promising, it should fulfill specific functional packaging requirements or at least show the same performance as conventional packaging in 3 essential aspects, namely containment, protection, and communication (Peelman *et al.*, 2016; Petersen *et al.*, 1999). According to Petersen *et al.* (1999), concerns related to characteristics of the product, properties of individual package, and environmental conditions must be considered before adopting bio-packaging as primary packaging material to achieve better product quality and estimated shelf-life.

Food consists of complicated matrices, which include dynamic processes (Luning and Marcelis, 2009; Petersen *et al.*, 1999). The right packaging material selection probably manages enzymatic, physical, and microbiological interactions within the food. Speaking of the packaging material itself, it should perform adequate barrier properties (impermeable to gases, water vapor, and aroma) so that the products stay in expected conditions. In addition, the mechanical properties (tear strength, resistance of puncture) should be tested in advance along with its ability to protect products from surroundings (temperature, relative humidity, light, etc.) (Iacovidou and Gerassimidou, 2018; Robertson, 2018; Alvarez and Pascall, 2011; Marsh and Bugusu, 2007; Petersen *et al.*, 1999). In summary, indeed, food product characteristics are an essential factor in selecting packaging material as it will influence the quality of the product (Ramos *et al.*, 2016; Marsh and Bugusu, 2007).

1.1.4 Beverages and quality

According to Patra, Choudhary, Madhuri, and Sharma (2019), generally, beverage includes tea, coffee, milk, juice, carbonated drinks, and alcoholic products. In the current trend of the food industry, beverages are considered a valuable player (Aadil, Madni, Roobab, ur Rahman, and Zeng, 2019), leading to market competitiveness. Consequently, the industries should be concerned about the quality since it is a crucial factor to achieve product satisfaction and prevent product failure (Paiva, 2013) to survive in the market (Ali, 2012). Ensuring beverage quality involves checking all raw materials, packaging materials, semi-finished goods, finished goods, and retained samples and correctly following the established procedures. It is an effort to reduce the risk of quality deviations, which can negatively affect effectiveness and cost (Lokrantz, Gustavsson, and Jirstrand, 2018).

The potential of leakage, the interaction between food and packaging materials as well as the migration of the substances can contribute to changes in the food products and/or the packaging used (Raheem, 2013; Marsh and Bugusu, 2007, Petersen *et al.*, 1999). Those kinds of deviations are responsible for many quality issues in beverage industries, which can lead to consumer rejection up to recall of the products. For instance, physical-chemical contamination, outbreaks of microorganisms, off-flavors, losses of nutrition, reduction of shelf-life, oxidation, enzymatic and nonenzymatic browning, as well as the change of color, texture, and odor during processing and storage (Aadil *et al.*, 2019). When it comes to implementing new packaging, including sustainable ones, those quality aspects cannot be ruled out.

1.1.5 Quality control activities

Quality control as part of the Quality Management System (QMS) is needed to manage quality issues mentioned above (Zhang, 2018; Luning and Marcelis, 2009). As stated by Luning and Marcelis (2009, p. 198), "the core mechanism of quality control is to maintain desired quality in product and production process by measuring product properties and processes, comparing actual measurement outcomes with the standard, and taking necessary corrective action to ensure that final quality will meet or exceed customer/ consumer needs and legal requirements." Realizing controlling is not only about inspection but also taking relevant corrective actions if deviations happen, the decisions are made by quality control system regarding out-of-tolerance of product properties/ people actions and corrective action as well as deviation from requirements on technological parameters and managerial system (Luning and Marcelis, 2009).

In performing control function, it is essential to identify relevant process parameters and control measures. One of the techniques used is Hazard Analysis and Critical Control Points (HACCP) (Luning and Marcelis, 2009). Following the trend of building quality into product, food companies are also in the process of developing a tool called Quality Analysis/ Assurance and Critical Control Points (QACCP) (Verkerk, Linnemann, and van Boekel, 2007).

1.1.6 QACCP and Critical Quality Point (CQP)

HACCP and QACCP are quite different. HACCP focuses on avoiding negative quality features, including physical, chemical, and microbial hazards to continuously reach safe product production and supply (Verkerk *et al.*, 2007). QACCP also thinks of keeping positive quality characteristics of the products by investigating quality points (QPs) but firstly, translating the quality into relevant quality attributes (Verkerk *et al.*, 2007).

QACCP is considered novel and there is no restriction for companies to implement a default format of it with specific steps and principles since it is still developed (Metaxioti, 2019). Nowadays, it is known that approximately three QACCP approaches are used (Issova, 2019). According to van der Spiegel and Vollebregt (2008), there are nine steps of QACCP as displayed in Figure 1.

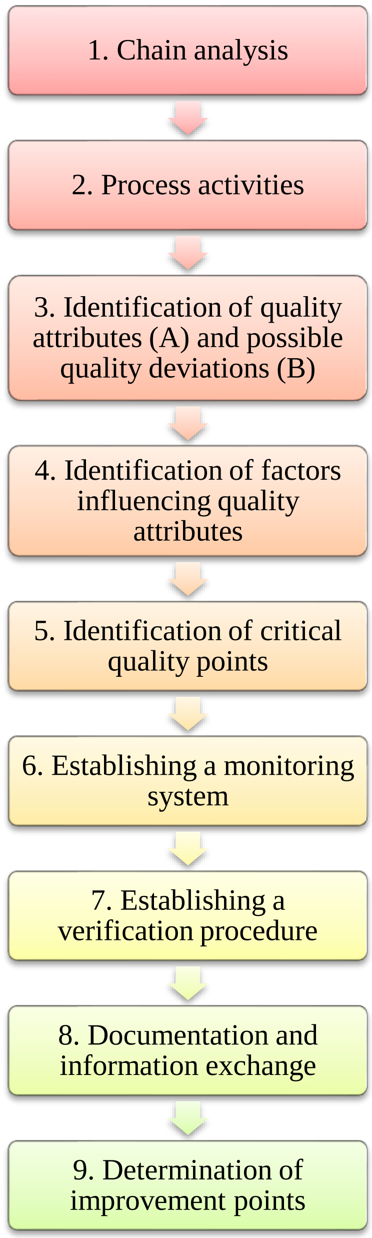

Figure 1. Steps of QACCP
(van der Spiegel and Vollebregt, 2008)

QACCP starts with the identification of a specific product supply chain (Verkerk *et al.*, 2007). Then the processes that happened in every chain are described in detail. Food product has their quality attributes, which can be classified into intrinsic attributes (health, sensory, safety, shelf life, and convenience) and extrinsic attributes (production system characteristics and assigned quality by marketing or communication such as sustainable) (Luning and Marcelis, 2009; Verkerk *et al.*, 2007). The quality attributes of the food product should be analyzed for control purposes.

Luning and Marcelis (2009, p. 25) stated, "the techno-managerial approach advocates the importance of understanding the behavior of both food and human systems and their interdependency." The statement explains that in such changes in food quality attributes in the chain, there are two important factors involved. It is not only about the food dynamic behavior (technological factors), but also may be supported by administrative conditions and the decision-making process from the people in charge (managerial factors). Therefore, Ali (2012) and van der Spiegel and Vollebregt (2008) added a step to QACCP about factors contributing to changes in quality attributes, defined as quality point (QP).

A change in quality attributes due to factors related to product and/ or process is a direction to identify the critical quality point (CQP) (Ali, 2012; van der Spiegel and Vollebregt, 2008; Verkerk *et al.*, 2007). CQP is defined as a factor(s)/ point(s)/ step(s) in processes where variation/ deviation in aspects concerning product and/or process may contribute to a significant change, whether it is unacceptable and/ or permanent, on the final product quality (Ali, 2012). Therefore, CQP must be controlled to prevent or reduce quality problems to an acceptable level (van der Spiegel and Vollebregt, 2008).

Steps 6, 7, and 8 of this QACCP tool are quite similar to HACCP steps about monitoring system, verification procedures, and documentation which are required to support appropriate control function. Lastly, it ends with finding points for improvement. Improvement is fruitful since it covers the way to increase productivity and customer satisfaction, reduce cost, and achieve higher quality levels (Luning and Marcelis, 2009).

1.2 Focus of the research

1.2.1 Type of sustainable packaging

Driven by environmental issues, nowadays, food/ beverage companies, together with packaging industries, have reduced the use of conventional packaging materials and developed alternatives (Peelman *et al.,* 2016; Petersen *et al.,* 1999). One of them is bio-based material. Bio-based material is defined as a material made wholly or partly from renewable resources (Iacovidou and Gerassimidou, 2018; Storz and Vorlop, 2013). It is an emerging trend as a solution for conventional plastics, which is nowadays made from 99% petrochemical origin (Molenveld *et al.,* 2015). As research and development grow, bio-based material is now used to pack various food products: fruit and vegetables, bread, dairy products, herbs and spices, organic cereals, beverages, etc. (Peelman *et al.*, 2016; Molenveld *et al.*, 2015). According to Molenveld *et al.* (2015), for beverages, as an example, bio-based materials may include carton with bio-based plastic layers and cap.

Furthermore, a study by Iacovidou and Gerassimidou (2018) predicted that the use of bio-based materials increases by 2020, with the total production rises from 2.05 million metric tons in 2017 to 2.44 million metric tons in 2022 (European Bioplastics, 2018). Therefore, it is interesting to study more about this prospective material, in the scope of food packaging, quality, and sustainability.

1.2.2 Type of beverage

Bio-based material is a novel substance that is continuously developed by institutes, food, and packaging industries for beneficial utilization. There are still a few product types packaged with this material in the market. Beverages is also one of an area of bio-based packaging application (Molenveld *et al.,* 2015). Alvarez and Pascall (2011) indicated that in the UK, a British company innovated a milk packaging consisted of cardboard and polylactic acid (PLA) as bio-based material from corn starch. In 2015, Tetrapak also launched beverage packaging with a bio-polyethylene (PE) coating as a substitute for plastics (Molenveld *et al.,* 2015). Meanwhile, Pepsi and its competitor, CocaCola, are growing to massively produce plant bottles (conventional plastic bottles with 30-100% bio-based content inside) for their soft-drinks products (Storz and Vorlop, 2013). Reflecting on these cited phenomena, the use of this material is possible and of various kinds. Therefore, the wide-ranging type of non-alcoholic beverages is selected for initial research, to study the typical quality problems associated with sustainable packaging adoption.

1.2.3 Quality attributes

Quality attributes, which are concretely divided into intrinsic and extrinsic, are required in identifying CQP. Intrinsic quality attributes are in-built with physical products, including sensory (odor, color, taste) and shelf-life (freshness, keepability) (Luning and Marcelis, 2009). Since these attributes are perceptible and can be considered representing consumers' satisfaction of the products (Imm, Heo, Choi, and Kang, 2017; Leong and Oey, 2017; Alvarez, 2009), the focus will be on these two groups.

1.2.4 Quality deviations

Deviation can be called as non-conformance (Kotra *et al.,* 2018). Quality deviation means any non-conformance with the quality specifications that are possible to occur to the product. Concerning sensory attributes, the quality deviations of beverage products are 'anything different' with odor, color, and taste. Deterioration associated with microbiological (spoilage/ microorganism outbreaks), chemical (non-enzymatic browning, oxidation), and physical (migration of compounds) are the examples of quality deviations that are related to shelf-life attributes (Luning and Marcelis, 2009) and relevant for beverages.

1.2.5 Type of industry

Regarding shelf-life as one of the quality attributes to be observed, it is important to focus the research on the packaged beverage industries, which mostly manufacture products with longer shelf-life compared to food service industries (restaurant, catering). Even though food service industries are starting the trend of sustainable packaging earlier by using bio-based plates, cups, and spoons for their meals, it is unlikely to include them in this research. Consumers will consume the foods as soon as possible, so there is almost no related concern about shelf-life.

1.2.6 Processes in the industry

Quality deviations are possible to happen in all steps of product manufacturing. However, as the packaging materials will have direct contact with food starting from the packaging process, merely the packaging process, storage, and distribution will be concerned.

1.2.7 Technological and managerial factors

The technological and managerial factors which are further determined are derived from food quality relationship by Luning and Marcelis (2009) that includes food and human behavior. Food behavior is related to food dynamics (product composition, enzyme activities, growth-rate of microorganisms), and technological conditions (temperature, equipment design/ layout, equipment, storage conditions, packaging concepts). Human behavior is dependent on human dynamics (people perceptions, interest, and/or attitude influencing decision-making) and administrative conditions (procedures, job descriptions, information systems). All the T-M factors found are considered as QPs.

1.2.8 CQP

There is more than one definition of CQP. van der Spiegel and Vollebergt (2008) stated that CQP is a step in the process in which control is needed to avoid or reduce quality loss to an acceptable level in the final product received by the consumers. Meanwhile, Ali (2012) defined CQP as a factor(s)/ point(s)/ step(s) in processes where variation/ deviation in product and/or process may have a decisive influence on final quality attributes, which is undesirable and/ or permanent. For this research, the definition used is the one from Ali (2012). Furthermore, it is demarcated that this research will be focused until CQP is identified (step 2-5 of QACCP in Figure 1). The starting point is step 2 (process analysis) instead of step 1 (supply chain) because the research will focus on manufacturing steps (company-level perspective), especially from the packaging process.

1.3 Research objective

Based on the undesirable impacts on society, there is an increased environmental concern regarding packaging (Clark, 2018). The global trend shows that consumers prefer more environmentally-friendly products, even on foods (Ramos *et al.*, 2016; Storz and Vorlop, 2013). There are food companies which are currently realizing this condition and struggling in reducing ecological footprints caused by their business. Company commitments towards sustainable packaging are clearly stated in the websites, to communicate to consumers, most of them mentioning a period between 2020 and 2025 as the deadline (Molenveld *et al.*, 2015; Storz and Vorlop, 2013). Corresponding with this issue, the objective of this research is to gain insight concerning possible quality deviations along with technological and managerial factors influencing sensory and shelf-life quality attributes, and CQPs in beverages packaged with bio-based materials to help food/ beverage companies dealing with the adoption of sustainable packaging.

1.3.1 General research question

What are the CQPs of packaged beverages with bio-based materials?

1.3.2 Specific research questions

1. What are the possible quality deviations in packaged beverages with bio-based materials, regarding sensory and shelf-life quality attributes?
2. What are the technological and managerial factors influencing sensory and shelf-life quality attributes of packaged beverages with bio-based materials?
3. What are the CQPs of packaged beverages with bio-based materials?

1.4 Research approach

Dealing with bio-based packaging for beverages, which was quite a new area of research, the initial approach taken was investigating the quality aspects of beverages in conventional packaging (part A). It was done by applying step 2-5 QACCP until the CQPs were determined. The research was then continued with identifying CQPs of beverages in bio-based packaging (part B), beginning with finding the functional properties of bio-based materials, especially bioplastics, that were gradually used as beverage containers.

CQPs of beverages in conventional packaging, along with the functional properties of bio-based materials for beverage packaging, were searched using an in-depth literature review method with the help of critical appraisal form. Web of Science and Scopus were used as primary sources to find relevant studies. Supposed the information obtained from those two sources was considered not sufficient/suitable, additional search strategies via Science Direct were carried out. Furthermore, this study also relied on an interview method to gain information. Specifically, these methods aimed to verify the results from literature analysis as well as to get additional insights, including the implementation process of bio-based packaging in the related companies. The experts could be representatives from beverage companies that were already using alternative materials for their products, in this case, plastics from renewable resources, and the beverage packaging companies which also produced sustainable packaging.

Data obtained from part A and part B were combined and analyzed to be able to solve the specific research questions 1-3. In detail, with respect to QACCP steps, after analyzing the results, the possible quality deviations (step 3B), technological and managerial factors affecting the quality attributes of beverages (step 4), and the CQPs (step 5) were expected to be answered.

2 Research methodology

This chapter discusses the approach and methods used to answer all specific research questions mentioned in chapter 1. The flowchart below displays the approach to be able to get information to answer each specific research questions. It consists of two parts: A) CQPs of beverages in conventional packaging and B) CQPs of beverages in bio-based packaging, including the functional properties of bio-based materials for beverage packaging. There are two research methods used, namely literature review and expert interviews, explained in the following section.

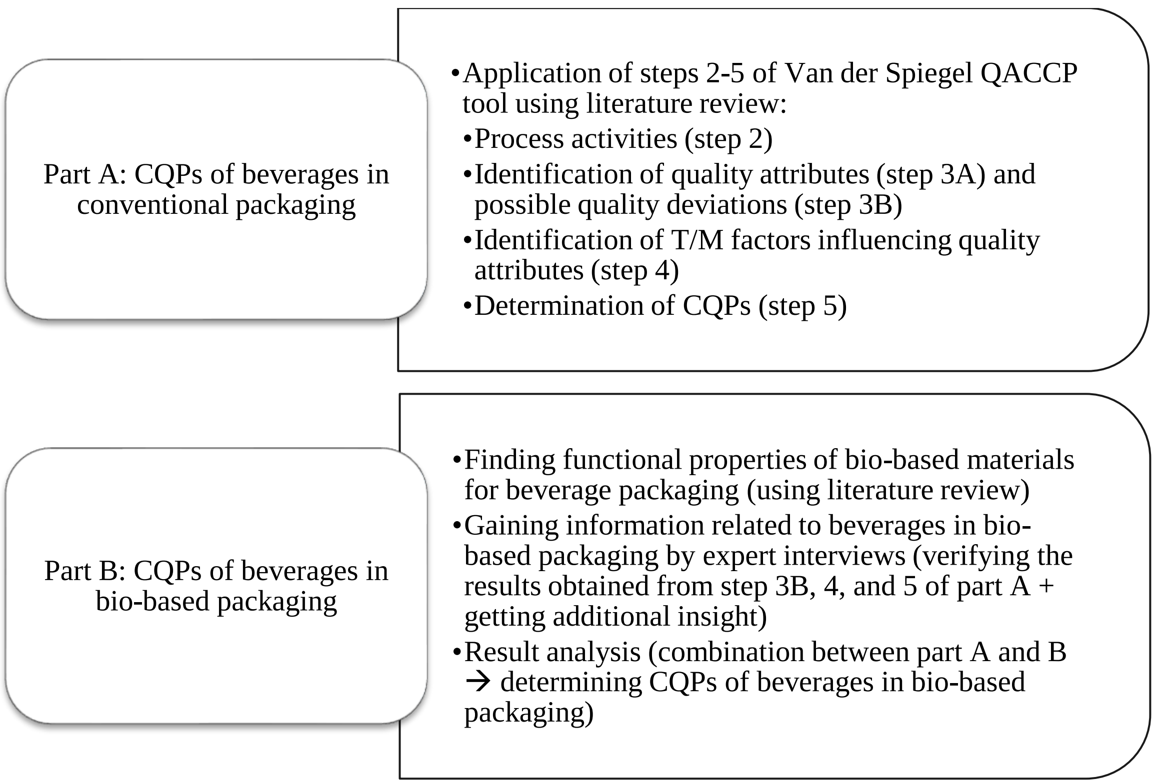

Figure 2. Flowchart of the main research approach

2.1 Literature review

The literature review was conducted to find information related to part A and B. This literature review aimed to gain scientific insight regarding (i) the QACCP steps applied to beverages with conventional packaging (part A) and (ii) functional properties of bio-based materials for beverage packaging (part B). In general, the core research activities related to literature review were:

2.1.1 Formulation of inclusion and exclusion criteria

For all results obtained, only publications in English and published in 1999-2019 were considered. The specific inclusion and exclusion criteria were shown in Table 1.

Table 1. Inclusion and exclusion criteria

No	What to search?	Inclusion and exclusion criteria	
Part A: CQPs of beverages in conventional packaging			
1	Process activities (step 2)	Inclusion	Packaging process of beverages, if possible until storage and distribution, but especially mention primary packaging process (bottling/ packing/ filling).
		Exclusion	The exact fermentation/ extraction process, treatment of beverage industry wastewater, chemical reaction process, the production process of packaging materials, beverage recycling process, and analysis related to energy used for producing beverages.
2	Quality attributes and possible quality deviations (step 3A & 3B)	Inclusion	Sensory and shelf-life attributes of non-alcoholic beverages together with changes/ defects/ deviations/ deteriorations related to beverages.
		Exclusion	Quality attributes and deviations of the whole form of beverage ingredients (coffee beans, tea leaves, fruits) or dry beverages or water, chemical analysis of volatile and non-volatile compounds in beverages, and structure modifications.
3	Technological/ managerial factors influencing quality attributes and CQPs (step 4 and 5)	Inclusion	Factors in milk and production steps (from packaging process until distribution) that influence sensory and shelf-life quality attributes, either from product properties/ technological conditions (T factors) or human dynamics/ administrative conditions (M factors). For M factors, relevant findings in association with beverages are included.
		Exclusion	Effect/ influence of plant diseases, information received by consumers, growing locations, maturity stages, additives, fortification, and advanced non-thermal preservation techniques on milk and juice quality.
Part B: Functional properties of bio-based materials for beverage packaging			
4	Bio-based materials for beverage packaging	Inclusion	Functional properties of bio-based materials used for packing food and beverages.
		Exclusion	Detail production process/ synthesis, the chemical structures, the application for building/automotive/ things other than food and beverages, and life cycle assessment (LCA) related to these materials.

2.1.2 Development of search strategies

The combination of various and simple keywords, along with filters, were listed to be able to maximize the chance of obtaining relevant references. A truncation, namely asterisk (*), helped replace multiple characters. A question mark (?) as one of the wildcards, was used as well to replace zero and one character. The quotation mark ("…") was applied to search for the exact phrase. Boolean operators method ('OR,' 'AND,' and 'NOT' function) was included. The detail search strategies were displayed in Appendix A.

2.1.3 Identification of relevant publications

The keywords formulated were executed in the database of the Web of Science and Scopus. Since many publications mentioned more technological factors, additional search strategies using Science Direct were conducted, only for managerial factors. For time efficiency, all publications obtained using the formulated keywords were screened based on inclusion and exclusion criteria. If the publication title was considered appropriate, the abstract was read twice. Suppose that the abstract was assumed not containing adequate information, the full texts from the introduction up to conclusion were scanned. Then, the publications were critically analyzed using a critical appraisal form for relevancy. The results of search strategies were also presented in Appendix A, where hits reflected all results appeared from the databases.

2.1.4 Analysis of relevant publications

Publications were analyzed with the help of a critical appraisal form, as shown in Table 2. Critical appraisal was started from general information (asking the title of the study, aim, type of study, and type of beverage discussed) then continued with the parts representing specific topics. The critical appraisal table containing the specific/ important information from relevant publications could be seen in Appendix B.

Table 2. Critical appraisal form

No.	Questions	Short answer	Detailed answer
Part A. General information			
1.	What is the aim(s)?		
2.	What is the type of study used?	Empirical/ review	
3.	What type of beverage is discussed?		
Part B. Process activities of packaged beverages			
4.	What are the process activities of packaged beverages described in the paper?		
5.	Is it for a beverage using conventional/ bio-based packaging?	Conventional/ bio-based	
6.	Is there any detailed step from the packaging process until the distribution mentioned?	Yes/no	
Part C1. Quality attributes of packaged beverages			
7.	Which quality attribute(s) is mentioned?	Appearance/ flavour/ texture/ shelf-life	
Part C2. Possible quality deviations in packaged beverages related to quality attributes			
8.	What are deviations (from quality attributes) that revealed from the paper?		
9.	Which type of deterioration is relevant?		
10.	Which quality attribute(s) is affected?	Appearance/ flavour/ texture/ shelf-life	
Part D. Techno-managerial factors influencing quality attributes			
11.	Which factor that influencing sensory and shelf-life quality attributes are mentioned?		
12.	Is it a technological/ managerial factor?	T/M	

No.	Questions	Short answer	Detailed answer
13.	In which process activity does the factor influence quality attribute(s)?		
14.	Which quality attribute(s) is affected?	Appearance/ flavour/ texture/ shelf-life	
Part E. CQP			
15.	Is variation in quality attributes acceptable for consumers?	Yes/no	
16.	Is the variation in quality attributes irreversible?	Yes/no	
Part F. (Functional properties of) bio-based materials for beverage packaging			
17.	Which bio-based material is discussed?		
18.	What are the functional properties/ other characteristics of this material?		

2.2 Expert interviews

The expert interview was a method used for supporting part B. The expert interviews aimed to get information regarding (1) the implementation of bio-based packaging in milk/ juice company; (2) the bio-based materials used for product packaging; and (3) quality aspects of product packaged with bio-based packaging which could help to verify the results obtained from the literature review. The details of expert interviews were described in the following sections.

2.2.1 Identification of experts

For data collection, the experts who participated in the interviews were those who fulfilled two criteria such as: (1) working in the milk or juice companies which are currently using bio-based materials for product packaging or at the beverage packaging industries at least three years; (2) the experts' job description can be related to product quality and/or packaging, or the experts were involved in the bio-based packaging implementation project from quality or packaging side.

In total, 35 companies have been contacted via personal LinkedIn, company email and phone, company website's message box, related social media (Facebook, Instagram), and visit the office. The details were 19 milk/ dairy companies, 12 juice companies, and 4 packaging companies. Luckily, 7 experts were willing to participate because the topic was interesting for them, and they were curious about the results. Mainly, phone and Skype calls were used to conduct interviews. Other experts suggested a written interview to give information due to their full schedule. For better understanding, follow-up questions and comments were sent to the experts, and they clarified vague answers obtained from filled-in questionnaire. The job position of the participating experts and how the interview was conducted were presented below.

Table 3. Job position of the experts and the details of the interview conducted

Expert	Job position	Type of company	Type of interview
Expert A	Packaging Development Manager	Milk company	Written
Expert B	Sustainable Packaging Development Manager		Written
Expert C	Packaging Support Officer		Phone call
Expert D	QESH Manager		Written
Expert E	QA/QC Manager	Juice company	Phone call
Expert F	QA Specialist		Phone call
Expert G	Sustainability Director	Beverage packaging company	Skype call

2.2.2 Design of the interview questions

The interview began by asking general questions about the interviewee's job and his/ her experience with bio-based packaging. It was then continued with three main parts: part A – the implementation of bio-based packaging in milk/ juice company, part B – the bio-based materials used for product packaging, and part C – product quality with bio-based packaging. A set of interview questions was presented in Appendix D.

2.2.3 Interview procedure

The formulation of the interview procedure was inspired by a publication by O'leary (2004). Firstly, the conversation was started with expressing gratitude for the cooperation, asking permission for recording, a short introduction focusing on the overview of research topic, the aims (verifying answers from literature review and getting additional practical information that was not initially thought), the duration, the structure of the interview, ended with confirmation from the interviewees whether they were clear enough or not. The interview was followed by asking interview questions, which were mentioned in section 2.2.2. The procedure of the interview could be seen in Appendix E.

2.2.4 Content/ data analysis

During the interviews, the results were summarized. At the end of each answer, the summary was confirmed to the experts. When the experts agreed upon the summary, it was then considered as the processed data. After the interview session, the recordings (raw data) were listened to once again to check if there was no important information left out.

For the questionnaires sent to the experts, the filled-in forms were reviewed twice, and the unclear answers were clarified again to them via email. This happened 2-4 times until the answers were assumed clear and reasonable enough. Data from all experts were displayed together in an overview table (see Table 8). It was then written in the chapter of results and discussions as reported data to show the patterns and additional insights gained through the interviews.

3 Results and discussions

This chapter presents the results and discussions of part A which focuses on finding CQPs in beverages with conventional packaging (using literature review) and part B about functional properties of bio-based materials for beverage packaging and the related CQPs (using literature review and expert interviews method).

3.1 Part A (CQPs of beverages in conventional packaging)

3.1.1 Process activities of beverages (step 2)

The search for process activities of beverages, including packaging process, storage, and distribution from two databases, resulted in a total of 814 publications. After checking all the titles and abstracts, whether the publications met inclusion and exclusion criteria, 109 publications obtained. From the analysis of these publications, 12 publications were found relevant after removing the duplicates. From 12 related publications, it was found that 2 were book chapters and 10 were empirical studies. All relevant publications discussed the steps of processing various types of beverages (for instance milk, juices, and drinks with the addition of other main ingredients (curd, whey, hibiscus, peanut, pine nut, and rice)) packaged with conventional packaging, mostly mentioned the processing stage until storage. 3 publications explained the filling process in detail.

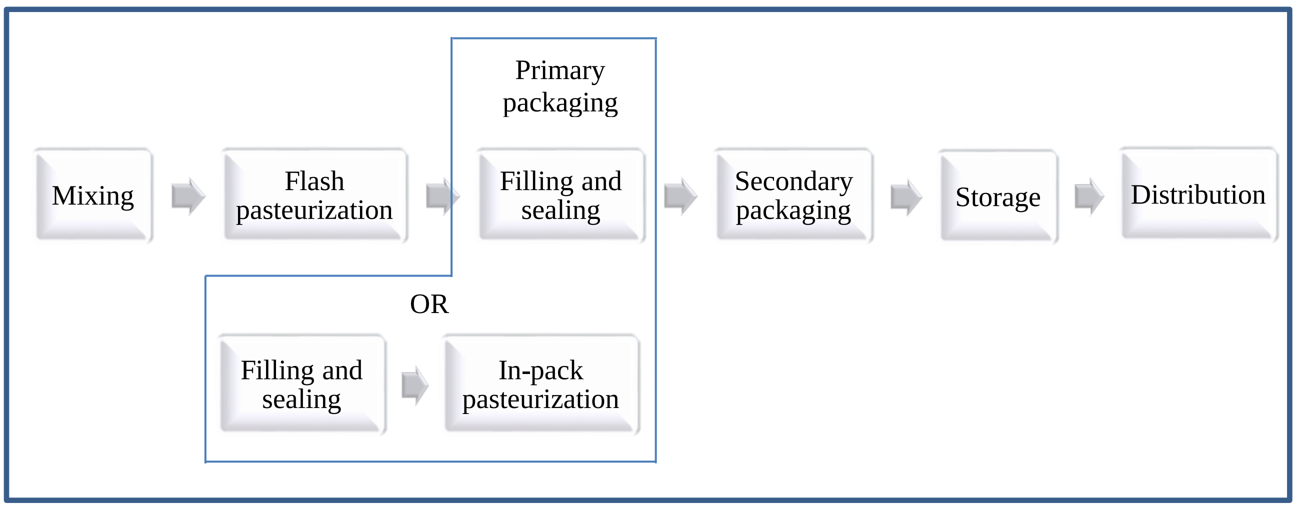

Figure 3. Process activities of beverages
(adapted from Andrade *et al.*, 2019; Barba *et al.*, 2017; Monteiro *et al.*, 2017; Pasvanka, Varzakas, and Proestos, 2017; Manfredi and Vignali, 2015; Ahmadian-Kouchaksaraei, Varidi, Varidi, and Pourazarang, 2014; Reyes-De-Corcuera, Goodrich-Schneider, Barringer, and Landeros-Urbina, 2014; Singh, Khemariya, and Rai, 2014; Bertolini, Bottani, Vignali, and Volpi, 2013; Singh, Jha, Singh, and Singh, 2012; Deshpande, Chinnan, and Phillips, 2008; Lee and Rhee, 2003).

As shown in Figure 3, the beverage processing starts with mixing/ blending all ingredients, heat treatment after or before primary packaging, secondary packaging, storage, and distribution. Beverage processing and packaging is aimed to satisfy consumers by providing desired quality beverages in a convenient size. The detail steps of the process depend on the microbiological characteristics of the raw and packaging materials along with the ingredients used, whether the product is added sugar, preservatives, etc., and heat-stable or not.

After treatments for special raw materials, all ingredients are mixed in a batch tank. The next process could be heat treatment (flash pasteurization) or filling then continued with in-pack pasteurization (the heating process is done after the product is packaged and sealed) (Andrade *et al.*, 2019; Barba *et al.*, 2017; Monteiro *et al.*, 2017; Pasvanka *et al.*, 2017; Ahmadian-Kouchaksaraei *et al.*, 2014; Reyes-De-Corcuera *et al.*, 2014; Singh *et al.*, 2014; Singh *et al.*, 2012; Deshpande *et al.*, 2008; Lee and Rhee, 2003). The core concept of product pasteurization is, the batch of product will be heated and stored at fixed temperature and time to reduce the microbiological level to an acceptable level so that the product is shelf-stable (Manfredi and Vignali, 2015).

Filling is a process when the liquid products meet their primary packaging, namely glass, plastic, or multi-layered carton box (Pasvanka *et al.*, 2017). It can be done with and without heat, depending on product characteristics and proposed shelf-life. According to Manfredi and Vignali (2015), hot and aseptic filling can reduce microbial growth and contamination risks since the hot temperature is involved. In hot filling, the drinks are hot-filled at a temperature between 88-92°C, capped, and then cooled down. In aseptic filling, first, the container and product will be sterilized separately, and then the cold product will be filled to the packaging, closed, and sealed in a sterile environment (Pasvanka *et al.*, 2017; Reyes-De-Corcuera *et al.*, 2014). Aseptic filling is considered better in preserving product quality since the heat treatment for products (approximately at 100-110^{o}C) is applied only for 0,5-1,5 minutes (Pasvanka *et al.*, 2017). Form-fill-seal (FFS) is another aseptic filling system used for a laminated/ multilayer carton. The packaging will be formed first, then filled with beverage and sealed continuously (Reyes-De-Corcuera *et al.*, 2014; Bertolini *et al.*, 2013).

Completed sealing process leads to the secondary packaging process such as labeling, coding, packing in a box/ cartoning, and palletizing (Manfredi and Vignali, 2015) and storage in finished goods warehouse before sold to consumers. Depending on product characteristics, products are stored and distributed at ambient temperature or in chilled condition.

3.1.2 Quality attributes and possible quality deviations in beverages (step 3)

A total of 838 publications were obtained from 6 search strategies applied for two databases. Based on exclusion criteria, publications talking about other forms of beverages (for instance, milk powder, coffee beans, tea leaves, etc.), water, and quality of food with the addition of beverages (e.g. quality characteristics of smoked beef with lemon juice) were removed when quick checking the titles. 145 documents were further analyzed and after removing the duplicate publications, 37 relevant publications were used to help giving information regarding quality attributes and possible quality deviations in beverages (steps 3A and 3B).

Quality attributes of beverages (step 3A)

Using the critical appraisal form, from 37 relevant publications, 27 publications (1 book chapter, 2 review papers, 24 empirical studies) were relevant for writing quality attributes of beverages. Different types of beverages, such as juices, milk, coffee, and tea, were the focus of the studies. Beverage quality attributes revealed from those papers were: a) appearance, including color; b) flavor (related to aroma and taste); c) texture; and d) shelf-life.

Table 4. Quality attributes of beverages

Quality attributes	Details
Appearance	Colour, turbidity, homogeneity, brightness
Flavor	Bitterness, sweetness, sourness/ acidity, astringency, fruitiness, aroma/odor (volatile compounds)
Texture	Mouthfeel, aftertaste, thickness, viscosity/ density, sandiness, cleanliness, creaminess
Shelf-life	Stability, freshness (no staleness, rancidity, microbial growth)

Regarding sensory and shelf-life aspects, four identified quality attributes and the components are displayed in Table 3. Based on literature analysis, for beverages, appearance and flavor are considered as the leading quality aspects. It is because those quality attributes will influence consumers' preference and acceptability of products (Eissa, Yaseen, Bareh, Ibrahim, and Mansour, 2018; Skoczylas, Korus, Tabaszewska, Gędoś, and Szczepańska, 2018; Evrendilek, Celik, Agcam, and Akyildiz, 2017; Tomadoni, Cassani, Viacava, Moreira, and Ponce, 2017, Tastan and Baysal, 2015; Laaksonen, Mäkilä, Tahvonen, Kallio, and Yang, 2013; Ratnasooriya, Rupasinghe, and Jamieson, 2010; Lopez-Nicolas, Andreu-Sevilla, Carbonell-Barrachina, and García-Carmona, 2009). Furthermore, besides the attributes mentioned earlier, the high quality of milk depends on textural characteristics such as pleasant mouthfeel and clean aftertaste (Alvarez, 2009). Sensory and shelf-life quality are correlated because defects in sensory aspects will positively reduce product shelf-life (Tomadoni *et al.*, 2017). Here is the explanation compiled concerning quality attributes of 4 types of beverages.

Juice

As various fruits are possible to be processed as juice, the color of the juice depends a lot on the fruit flesh (Aishah, Hannah, and Alyani, 2016). For example, the color of the carrot and orange juice is orange, while strawberry juice has a red color. It is the pigment compounds that play a role in juice color, such as lycopene in guava juice, carotenoids in carrot juice, or anthocyanins in pomegranate juice (Chen, Bi, Guo, Xing, and Che, 2019; Aishah *et al.*, 2016; and Tastan and Baysal, 2015).

Juice flavor, described as taste and aroma, is also various with respect to the natural taste and smell of the fruit (Laaksonen *et al.*, 2013). Specifically, about the aroma, 5 main components are contributing to the specific juice aroma as cited from Lopez-Nicolas *et al.* (2009): R-farnesene (green herbaceous, mild sweet), 1-butanol (light-fruity, cheesy), hexyl acetate (sweet fruity), butyl acetate (fresh, apple-like, fruity), and hexanal (grass-like, green, fruity). Regarding the taste, phenolic compounds are responsible for astringency and bitterness, and sweet and sour tastes are dependent on the balance between sugar and acid content (Hemalatha *et al.*, 2018; Laaksonen *et al.*, 2013; Ratnasooriya *et al.*, 2010). However, it is common that for marketing purposes, fruit juices are diluted with water and sweeteners so that the bitterness, astringency, and sourness can be masked resulting in higher consumer acceptability, but consequently, the original flavor of the juice may be altered (Eissa *et al.*, 2018; Laaksonen *et al.*, 2013).

Besides filtration, the addition of pulp and breakdown of pectin molecules are the reason why juices have a clear or cloudy appearance as those components increase turbidity (Chen *et al.*, 2019; Tastan and Baysal, 2015; Rodrigo *et al*., 2003). In addition, pulp amount and pectin content also contribute to juice viscosity. The more pulp and pectin, the more viscous the juice will be (Hemalatha *et al.*, 2018; Hurtado *et al*., 2017; Laaksonen *et al.*, 2013).

With respect to shelf-life attributes, low pH properties of the juice are beneficial as it does not support the growth of pathogen bacteria (Evrendilek, Celik, Agcam, and Akyildiz, 2017). However, acid-tolerant microorganisms like yeasts and molds can still grow and may cause cheesy and buttery off-flavor and marmalade flavor along with changes in taste due to fermentation (Hurtado *et al*., 2017).

Milk

Milk color is white to off-yellow, depending on fat carotene content (Alvarez, 2009). In soymilk, because of higher soy composition, it may have cream color (Bolarinwa, Aruna, Adejuyitan, Akintayo, and Lawal, 2018). However, the milk color is not limited to a whitish color. Milk can be brown, pink, yellow, or sometimes green according to the flavor addition (Della Lucia *et al.*, 2016). Suspended fat along with proteins and minerals plays a role in milk opacity (Alvarez, 2009), while casein in milk can influence milk viscosity (Bulatović, Krunić, Vukašinović-Sekulić, Zarić, and Rakin, 2014). In terms of textural attributes, milk is considered to have a good quality if it is not very heavy/ dense so that it can be poured easily. When it is drunk, good milk has no slimy and greasy aftertaste (Alvarez, 2009). Cow milk has a typical flavor profile since it contains natural compounds. Additionally, the lactose content and milk minerals lead to a slightly sweet and salty taste on milk (Alvarez, 2009). For soymilk, the typical flavor which maybe not preferred by a group of consumers can be modified by adding fruit extract, sweeteners, and more pleasant aromas (İçier, Gündüz, Yılmaz, and Memeli, 2015). Microbial growth in milk is the main factor of its shelf-life reduction. Microorganisms can cause barny and shrimpy flavor along with creaminess (Martin *et al.*, 2016; Wiking, Frøst, Larsen, and Nielsen, 2002).

Coffee

Coffee is usually dark brown as a result of the roasting process. The roasting is also a reason why coffee has a robust bitter taste typically if it is not added with sugar or milk (Andueza, Vila, Paz de Peña, and Cid, 2007). Moreover, coffee leaves a characteristic aftertaste. The viscosity of coffee will be different depending on the coffee kinds. Bertrand *et al.* (2012) and Ribeiro, Augusto, Salva, and Ferreira (2012) revealed that the aroma of coffee is the most important among other properties since the volatile compounds of coffee can indicate its character and quality. Taste (sweetness and acidity), which also helps to determine coffee quality, depends on phosphoric, malic, and citric acid (related to sucrose content) (Laukalēja and Krūma, 2018). Coffee drink, which is sometimes liquid or more viscous, is still considered in a good shelf-life when it is free from fermented, musty, woody, earthy, and pungent odor (Andueza *et al.*, 2007). The aftertaste, bitterness, and astringency of coffee increase during storage (Kreuml, Majchrzak, Ploederl, and Koenig, 2013).

Tea

Tea quality is determined by sensory attributes such as color, flavor (taste, aroma), and overall appearance (Zhu *et al.*, 2019). As known for black tea, the formation of color is due to theaflavins and thearubigins pigments. Theaflavins are orange and bright, and thearubigins has red-brown color. Besides color, these pigments influence the mouthfeel and flavor of tea as well. Theaflavins are responsible for astringency while thearubigins give thick sensation when drinking tea (Karadağ, Avci, Kasapoğlu, and Özçelik, 2016).

Possible quality deviations (step 3B)

From 37 relevant publications for steps 3A and 3B, 16 were considered suitable since they discussed quality deviations. In detail, 11 empirical studies mentioned possible quality deviations happen in juice, and for milk, there were 5 publications (1 book chapter, 1 review, 3 empirical papers). Since all references obtained talked about milk and juices, for the next steps, the research was scrutinized to two types of beverages, namely milk and juices.

Table 5. Possible quality deviations occurred in milk and juice

Possible quality deviations	Type of deterioration	Beverages		Quality attributes affected
		Milk	Juices	
Enzymatic browning	Biochemical	-	✓	Appearance
Non-enzymatic browning (NEB)/ Maillard reaction	Chemical	✓	✓	Appearance, flavor, shelf-life
Oxidation	Chemical	✓	✓	Appearance, flavor, shelf-life
Microbial spoilage	Microbiological	✓	✓	Appearance, flavor, texture, shelf-life
Degradation of compounds	Biochemical, chemical, microbiological	✓	✓	Appearance, flavor

As shown in Table 4, NEB, oxidation, degradation of compounds, and microbial spoilage are common possible quality deviations occurred in milk and juices affecting all quality aspects. Enzymatic browning is also likely to happen in juices, mostly due to temperature abuse and enzyme activities resulting in the changes of appearance and flavor. By nature, enzymatic browning is one of the biochemical reactions as it involves enzymes, whereas the Maillard reaction is a typical chemical deviation besides oxidation. The microbial spoilage is a distinct form of microbiological deterioration. Last but not least, the degradation of compounds is very complex (a combination of chemical, biochemical, and microbial deviations), taking into account various degradation causes. Overall, the possible quality deviations in milk and juices with conventional packaging will lower the product quality, which consumers perceive as discoloration/off-color/color change, off-flavor/off-odor, and texture change. The findings concerning possible quality deviations are described in the following paragraphs.

Non-enzymatic and enzymatic browning

Non-enzymatic browning (NEB) or Maillard reaction is mostly reported among all relevant publications. NEB is a complex chemical reaction between reducing sugars and amino acids forming brown polymers, namely furfural and 5-hydroxymethylfurfural (5-HMF) (Agcam, Akyildiz, and Evrendilek, 2016; Chia, Rosnah, and Noranizan, 2012; Falade, Babalola, Akinyemi, and Ogunlade, 2004).

NEB usually happens with heat processing or lengthy storage time (Agcam *et al.*, 2016; González, Vegara, Martí, Valero, and Saura, 2015; Li, Miao, and Jiang, 2009). NEB leads to color deterioration in the products, including milk and juices (Evrendilek *et al.*, 2017; Chia *et al.*, 2012; Alvarez, 2009; Li *et al.*, 2009; Falade *et al.*, 2004). According to Falade *et al.*, 2004, off-flavors also may happen due to NEB. In case of juices containing ascorbic acid like mango and citrus juice, with the influence of oxygen and light, the ascorbic acid will be oxidized and degraded resulting in browning and flavor change as its degradation can be associated with NEB (Agcam *et al.*, 2016; Chia *et al.*, 2012; Falade *et al.*, 2004).

Besides NEB, browning can be caused by activities of enzymes contained such as polyphenol oxidase (PPO) and peroxidase (POD) (Evrendilek *et al.*, 2017; Li *et al.*, 2009). It is an agreement with a previous study conducted by Caminiti *et al.* (2012), stating that the enzymatic browning process caused lemon, apple, and peach juice to decrease their bright color.

Oxidation

Oxidation occurs when food/ beverage compounds react with oxygen, even though it may be induced by light, temperature, and catalysts/ enzymes (Evrendilek *et al.*, 2017; Huvaere and Skibsted, 2015; Chia *et al.*, 2012). Oxidation of sensitive compounds contained in milk and juice such as lipids, proteins, ascorbic acid, and carotenoids (color pigments) reduces the freshness as it influence discoloration and the formation of off-flavor (Silva *et al.*, 2016; Huvaere and Skibsted, 2015; Chia *et al.*, 2012). Common off-flavor due to oxidation is associated with metallic, burnt, medicinal, and activated sunlight flavor that can be perceived by consumers as stale (Alvarez, 2009).

Microbial spoilage

Bacteria, yeasts, and molds may harm product quality attributes as they influence appearance, flavor, and texture resulting in the reduction of shelf-life (Tomadoni *et al.*, 2017; Martin *et al.*, 2016; Bajwa and Mittal, 2015). When these microorganisms grow, they will release enzymes (amylases, proteases, and pectinases), break down the sugar structures, causing an alteration in total soluble solids. The products of fermentation (acids and gases) reduces the pH level as well (Agcam *et al.*, 2016; Bajwa and Mittal, 2015; Chia *et al.*, 2012).

Milk is vulnerable to microbiological deterioration since it has high water activity and nutritional value (Martin *et al.*, 2016). In milk, microbial spoilage is commonly related to post-pasteurization contamination by psychrotolerant Gram-negative bacteria such as *Pseudomonas* spp. or microorganisms that survive pasteurization such as Gram-positive bacteria (Martin *et al.*, 2016; Bajwa and Mittal, 2015; Alvarez, 2009). For juice, its low pH and high acid content properties normally protect the product from the growth of microorganisms (Silva *et al.*, 2016; Chia *et al.*, 2012). On the other hand, fruit juice is still at risk of spoilage caused by osmophilic and acid-resistant microorganisms like molds and yeasts (*Saccharomyces cerevisiae*) since low pH in fruit juice is their optimal condition to grow (Silva *et al.*, 2016; Chia *et al.*, 2012).

Degradation of compounds

During storage, the sensory quality may change due to the degradation of compounds. A study by A study by Wiking *et al.* (2002) indicated that lipolysis and proteolysis are two of the essential deterioration in milk, and these kinds of degradation lower the shelf-life. Concerning unstable fat characteristics, various treatments in milk lead to free fatty acid formation, causing off-flavor. Meanwhile, protein is natural to be degraded because of the activities of microorganisms or plasmin-plasminogen (autoproteolysis).

Nonetheless, the amino acid in milk also can be degraded by light exposure (Alvarez, 2009). It produced methional, dimethyl disulfide, and trisulfide, resulting in off-flavors related to sulfur (fishy, typical cabbage aroma) (Huvaere and Skibsted, 2015). Speaking of juices, fruit pigments that contribute to juice color are found to be very sensitive. Pigments like anthocyanins tend to experience degradation during processing and storage time leading to color change (Tastan and Baysal, 2015).

Compounds degradation is a complex reaction because of the many possible factors involving. It may be the result of microbial growth, but mostly due to enzyme activities like in proteolysis, lipolysis (called biochemical reactions), and fluctuation in processing and storage conditions (chemical reactions).

3.1.3 T-M factors influencing quality attributes of milk and juices (step 4)

In the first search, a total of 886 publications appeared when applying search strategies for T-M factors influencing quality attributes of milk and juices. Screening on the total hits (publication titles and also abstracts when the titles were appropriate) resulted in 169 references to be further analyzed. Duplications were removed, and the final relevant publications obtained so far were 29 in total consisting of 1 book chapter, 3 review papers, and 25 empirical articles. Since the managerial factor found from the literature was few (only 1), additional search strategies for managerial factors were formulated with the help of another database: Science Direct, besides Web of Science and Scopus. From 443 total hits, 6 relevant publications were obtained after critically analyzing 43 publications, and they were all book chapters. Overall, in total, 35 publications were discussing technological and managerial factors.

Technological factors

From 35 relevant publications, 29 were about technological factors (25 empirical studies, 3 review papers, 1 book chapter). Light, the temperature of filling, pasteurization, and storage, time of pasteurization and storage, oxygen, microbial load, and packaging materials were the 9 technological factors identified from literature analysis.

Light

Light contributes to variation in color, flavor (taste, aroma), and textural attributes, especially during storage (Martin *et al.*, 2016; Tobolková *et al.*, 2013; Intawiwat *et al.*, 2010; Kontominas, 2010; Karatapanis, Badeka, Riganakos, Savvaidis, and Kontominas, 2006; Conrad, Davidson, Mulholland, Britt, and Yada, 2005; Mestdagh, De Meulenaer, De Clippeleer, Devlieghere, and Huyghebaert, 2005). As shown in Figure 4, the total color difference of juice stored in light conditions was significantly higher than the juice stored in dark conditions because of the higher pigment destruction (Tobolková *et al.*, 2013). Light-induced off-flavours are various, ranging from burnt, oxidized, stale taste to rancid odor, also depending on the packaging materials used (Intawiwat *et al.*, 2010; Karatapanis *et al.*, 2006). When there is a sufficient amount of light, it can penetrate to the packaging material and trigger the product compounds to form carbonyl compounds (hexanal, pentanal, heptanal) and dimethyl disulfide resulting in deterioration (Karatapanis *et al.*, 2006). It is also in line with the experiment conducted by Martin *et al.* (2016) reporting that in a short time (around 4 hours), LED light exposure can reduce the flavor quality of the milk by a mechanism of oxidation and on a 9-point scale, the consumer liking score may decrease 0,5 point. According to Karatapanis *et al.* (2006) and Mestdagh *et al.* (2005), packaging with light barrier, typically multilayers with pigmented/ opaque inner layer, was considered adequate to keep the product from photooxidation, compared to clear, UV filter, and O_2 binding materials.

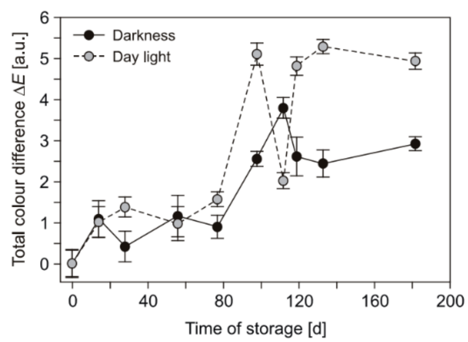

Figure 4. Total color difference (ΔE) of pineapple juice on storage time at constant temperature (T=7ºC) and different light conditions
(Tobolková *et al.*, 2013)

Pasteurization temperature

Different types of liquid products undergo flash pasteurization right after the filling and sealing process are done. Pasteurization here aims to inactive enzymes that contribute to deterioration and kill microorganisms either in products or the packaging materials (Kontominas, 2010). From literature analysis, it is found that the temperature of pasteurization influences sensory and shelf-life quality attributes of the products by at least 2 mechanisms (Wang, Zhan, Zhang, and Xi, 2018; Hajar-Azhari, Shahruddin, and Rahim, 2018; Kunitake, Ditchfield, Silva, and Petrus, 2014; Bhattacherjee, Tandon, Dikshit, and Kumar, 2011). Primarily, the NEB values will increase as the effect of the Maillard reaction. As a consequence, the juice will have browny darker color (decrease in lightness, increase in yellowness and redness) (Hajar-Azhari *et al.*, 2018; Bhattacherjee *et al.*, 2011). Other than NEB/ Maillard reaction, color changes can be induced by peroxidase enzyme, which is activated by thermal treatment (Kunitake *et al.*, 2014). Furthermore, a higher degree of pasteurization temperature would lead to off-flavors like the warmed-over or over-cooked taste and loss of natural aroma (due to the decline of ester compounds) (Wang *et al.*, 2018; Fang, Zhang, Sun, and Sun, 2006). In the case of milk, excess of temperature may lead to denaturation of proteins along with caramelization of lactose, causing undesirable milk texture and mouthfeel (Kontominas, 2010).

Pasteurization time

Pasteurization time is always correlated with temperature. Longer time of pasteurization in specific temperature is not appropriate since it may give changes in texture, flavor, and color attributes (more viscous, caramelized/ burnt/ over-cooked/ warmed-over taste and aroma and darker color) just the same as higher pasteurization temperature in specific time (Karmakar, Ghosh, and Gangopadhyay, 2011; Kontominas, 2010). Additionally, it is proven that with the same pasteurization temperature (90^{o}C), a slightly longer time of berry juice pasteurization contributed to a higher decrease of anthocyanin level (a pigment which is responsible for red color in berry fruits): 30s (4% decrease) compared to 60s (9% decrease) (Weber and Larsen, 2017). Therefore, a combination between time and temperature of pasteurization (optimal conditions) should be reached.

Filling temperature

A study by Siegmund, Derler, and Pfannhauser (2004) indicated that filling temperature could be a reason for flavor variations in beverages, in this case, large variant fruit juices (apples, oranges, lemons, grapefruits, pineapples, passion fruits, apricots, bananas, peaches, and mangoes). Compared to aseptic filling for carton packaging, the hot filling process resulted in the higher concentrations of compounds named dimethylsulfide and furancarboxaldehyde, a degradation product of sulfur and ascorbic acid, respectively, in products packaged with glass bottles. Furancarboxaldehyde, tested as an indicator for heat-treated juices, plays a partly significant role in causing off-flavors experienced by the juices such as loss of fruity taste along with the formation of burnt, stale, and oxidized aroma.

Storage-distribution temperature

During storage and transportation, the increasing temperature negatively affects appearance, taste, odor, and texture of milk and juice drinks (Marsol-Vall, Laaksonen, and Yang, 2019; Kaddumukasa, Imathiu, Mathara, and Nakavuma, 2017; Bhattacherjee *et al.*, 2011; Beltrán, Perez-Lopez, Lopez-Nicolas, and Carbonell-Barrachina, 2009; Esteve, Frígola, Rodrigo, and Rodrigo, 2005; Sharma, Kaushal, and Sharma, 2004; Simon and Hansen, 2001). Marsol-Vall *et al.* (2019) founded that volatile components and aroma attributes of blackcurrant juices remained constant in refrigerated temperature (4ºC) compared to ambient temperature (25ºC). It was because the heat generated changes to 4 main odor-active compositions, which were responsible for blackcurrant aroma perception. Figure 5 displays the differences between color, taste, and aroma of mango juices concerning storage temperature and time. Higher storage temperature accelerates quality attribute variations due to degradation of essential compounds such as pigments, phenolic compounds, and essential oils (Oliveira, Ramos, Minim, and Chaves, 2012; Esteve *et al.*, 2005).

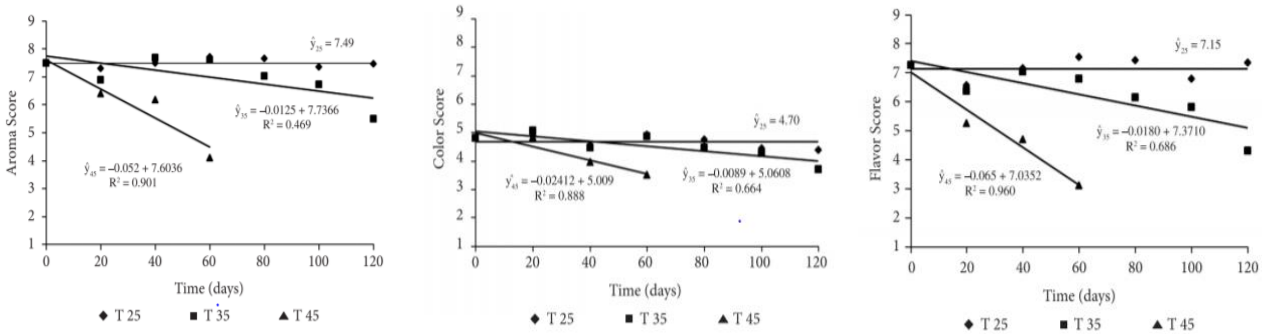

Figure 5. The behavior of the flavor and color scores of whole mango juices stored at 25ºC, 35ºC, 45ºC (Oliveira *et al.*, 2012)

Storage-distribution time

Within storage-distribution time, many inevitable reactions may occur. The reactions can be from external conditions or induced by the compound inside the product itself with the influence of packaging used (Oliveira *et al.*, 2012; Gliguem and Birlouez-Aragon, 2005; Sharma *et al.*, 2004). Moreover, in the case of juices and milk, gradually ascorbic acid will degrade, protein denaturation and Maillard reaction may slowly develop affecting color, texture, and flavor (taste and aroma) (Gliguem and Birlouez-Aragon, 2005; Burdurlu and Karadeniz, 2003). For instance, regardless of storage temperature, in 9 months, the lemon juice would lose its normal color due to the rise of NEB-related compounds (furfural, hydroxymethylfurfural). The components contributing to the taste and aroma like phenols, ascorbic acid, amino acids, and total sugars experienced a consistent decrease as well (Sharma *et al.*, 2004). Lastly, more prolonged contact between packaging materials and the product probably increases the chance of migration and/ or scalping (Kontominas, 2010).

Microbial load

One of the technological factors found is microbial load of the product, either from contamination (unhygienic processes, machines, packaging material, and personnel behavior) or microflora which survive pasteurization (Martin, Boor, and Wiedmann, 2018; Kaddumukasa *et al.*, 2017; Chavan, Chavan, Khedkar, and Jana, 2011; Karmakar *et al.*, 2011; Kontominas, 2010). Spoilage by microorganisms tends to cause biodeterioration leading to unacceptable color, texture, and flavor profile. In a particular condition, microorganisms can produce acids and gases influencing the product's natural flavor, pigments deteriorating the color, along with exopolysaccharides and gel so that the consistency will be slimy and ropy/ thick (Martin *et al.*, 2018; Chavan *et al.*, 2011). This biodeterioration finally reduces the products' shelf-life (Kaddumukasa *et al.*, 2017; Kontominas, 2010; Simon and Hansen, 2001). Figure 6 implies that regardless of the storage and pasteurization temperature-time, microbes can grow with the support of a sufficient amount of oxygen and/ or nutrients.

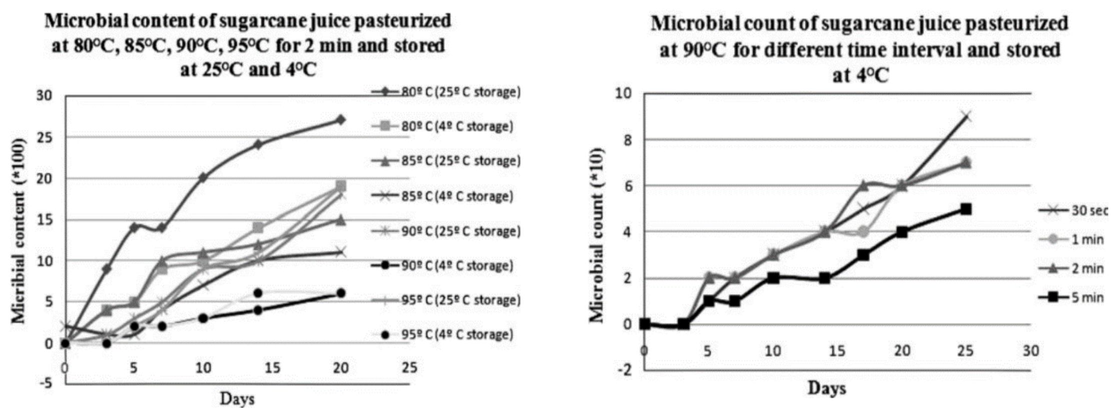

Figure 6. The microbial load of sugarcane juice in various storage and pasteurization time-temperature (Karmakar *et al.*, 2011)

Oxygen

Besides light, the presence of oxygen in the headspace of the packaging or because of packaging permeability is also important as it contributes to oxidation and lower the color and flavor quality. In addition, oxygen is beneficial for aerobic spoilage microorganisms like *Pseudomonas* spp. It is undoubtedly influenced by the packaging material used. Normally, fresh and desirable color, taste, and aroma are likely to be achieved by the product that uses multilayer packaging (carton, polyethylene, cardboard, aluminum foil) since plastic and aluminum have a sufficient gas barrier (Kontominas, 2010; Beltrán *et al.*, 2008).

Packaging material

Packaging material plays a big role in limiting deterioration concerning sensory and shelf-life quality attributes (Min, Zhang, and Yang, 2011; Intawiwat *et al.*, 2010; Kontominas, 2010; Beltrán *et al.*, 2008; Karatapanis *et al.*, 2006; Moyssiadi *et al.*, 2004; Zygoura *et al.*, 2004; Gliguem and Birlouez-Aragon, 2005; Mestdagh *et al.*, 2005). It is a barrier between the product and external conditions. To protect milk and juices from deviations, at least the packaging should give sufficient barrier to light, oxygen and should not be reactive of interaction to prevent migration and/ or scalping (Kontominas, 2010). Beltrán *et al.* (2008) compared the influence of different packaging materials on the shelf-life of orange juices. Transparent PET bottles and packed cartons consisting of different functional layers were used. Throughout storage, shelf-life of the juice in PET bottles was shorter than the cartons. Min, Zhang, and Yang (2011) conducted another study focusing on packaging thickness. Packaging with a thicker wall limits the oxygen to transfer to the orange juice, so the decrease of color and flavor and microbial spoilage may be minimized. Regarding the material itself, the nature of packaging materials (polarity-size-hydrophobicity) affects the migration phenomenon as well (Kontominas, 2010). In Figure 11, it can be seen that during storage, the different combination of packaging materials results in different taste and aroma of milk.

Packaging material^{a}	Score^{b}/comments Days of storage at 4 °C				
	0	1	3	5	7
Clear glass bottle	$5^{a,*}$	5^{a}	3.5^{c}/Slightly stale	3.0^{c}/Slight oxidized flavour	1.8^{b}/Oxidized flavour
Clear PET bottle	5^{a}	4.4^{b}	3.3^{b}/Plastic taste	2.5^{c}/Plastic taste, oxidized flavour	1.1^{b}/Plastic taste, oxidized flavour
Pigmented PET bottle	5^{a}	4.5^{b}	3.5^{c}	2.7^{c}/Plastic taste, oxidized flavour	1.2^{b}/Plastic taste, oxidized flavour
3-Layer pigmented, coextruded HDPE bottle	5^{a}	5^{a}	5^{a}	4.1^{a}	2.9^{a}/Stale
Monolayer pigmented HDPE bottle	5^{a}	5^{a}	4.3^{b}	3.4^{b}/Slightly stale	2.9^{a}/Stale
Coated paperboard carton	5^{a}	5^{a}	4.6^{b}	3.6^{c}/Slightly stale	3.1^{a}/Stale, fruity

Figure 7. Flavour evaluation of pasteurized milk packaged in various containers during storage at 4^{o}C
[a]HDPE = high-density polyethylene, PET = polyethylene terephthalate. [b]Numerical scale of scoring: very good = 5, good = 4, fair = 3, poor = 2, very poor = 1, unfit for consumption = 0 (Karatapanis *et al.*, 2006).

Managerial factors

From 35 relevant publications, 7 were about managerial factors (6 book chapters and 1 review article). Procedures, production along with storage and distribution control, and compliance to procedures and quality standards were the 4 managerial factors identified from literature analysis.

Procedures

Detail procedures in the manufacturing plant can help the operators perform better as they will know how to do their jobs correctly and what should be the focus of the job along with the reasons. For example, to deal with post-pasteurization contamination (PPC) that causes product off-flavors, detail cleaning and sanitation procedures/ protocols are needed by the employees, especially for the food-contact surfaces. Unclear procedures lead to incorrect concentration of cleaning chemicals used, even inappropriate cleaning methods resulting in biofilms, the worst case (Martin *et al.*, 2018; Martínez-Gonzáles and Castillo, 2016). Procedures for the maintenance of production machines should be provided as well (Dudeja and Singh, 2017). Overall, clear and detail procedures will support the production control, and it is recommended for food manufacturing units to establish a period of monitoring to check the relevancy and effectiveness (Dudeja and Singh, 2017).

Production control

Control on the process and product parameters are the parts of production control. With respect to the packaging process, temperature control, as an example of process parameter control, is applied to pasteurization, filling, and sealing. Control on product parameters includes determination of physicochemical and sensorial product properties by sampling in each crucial step such as pH, Brix, viscosity, gelation, titratable acidity, essential oils/ pulp/ fat content along with appearance, texture, taste, and aroma as the main sensory quality attributes of milk and juices (Aadil *et al.*, 2019; Berk, 2016; Shan, 2016). The QC team conducts those routine control activities. As discussed by Shan (2006), in doing production control, the QC team is also responsible for regular inspection related to operators and the environment since there is an inevitable contact with products.

Storage-distribution control

Managerial controls after the finished goods are ready to be stored and distributed are related to product handling, temperature control, and humidity control if necessary since those points contribute to product degradation or contamination (Aadil *et al.*, 2019; Baruffaldi, Accorsi, Santi, Manzini, and Pilati, 2019; Dudeja and Singh, 2017; Martínez-Gonzáles and Castillo, 2016; Shan, 2016). Regarding product handling, the conveyances and bulk containers that contact with the products should be controlled to minimize the risk of contaminating food and packaging (made from inert materials, easy to be cleaned or disinfected). During storage and transport, the products should be placed in the conditions that can protect them from direct sunlight, rain, dust, dirt, and collision. The separation between two or more different products considering their properties (toxic, harmful, corrosive, odorous) is also needed to be taken into account (Dudeja and Singh, 2017; Shan, 2016).

The temperature and humidity control are the ways to set the external conditions for products (Baruffaldi *et al.*, 2019; Dudeja and Singh, 2017; Shan, 2016). Baruffaldi *et al.* (2019), in their publication, indicated that inappropriate temperature and humidity irreversibly and unacceptably change the quality attributes of packaged finished goods due to the degradation of compounds and microbial spoilage. Furthermore, companies need to keep records of temperature and humidity for tracking and tracing, along with monitoring purposes (Shan, 2016).

Compliance of employees

To achieve better product quality, food processing companies need to develop complete and understandable procedures based on quality standards applied by those companies, such as ISO, HACCP, GMP, GHP, etc. The quality standards and company procedures are normally introduced to the employees through the company training. One of the training aims is to impart responsibilities to maintain product quality among all employees (Aadil *et al.*, 2019). Compliance with quality standards and procedures is essential as it is a real form of responsibility that can be done by the employees. Otherwise, there are product deviations/ discrepancies and defects during or after manufacturing processes. For example, if the operators do not comply with product handling SOPs, the products may be leaked due to collision or have different aromas as the separation zones are disregarded. Related to GHP, inadequate handwashing supported with unhygienic personal behaviors has a bigger chance of microbial contamination to the products. However, the training itself is considered not effective for ensuring compliance of employees. The help of CCTV, sensors, strict monitoring by senior operators and punishments are required (Aadil *et al.*, 2019; Dudeja and Singh, 2017).

3.1.4 CQPs (step 5)

As shown in Table 5, all technological and managerial factors (QPs) identified from step 4 are considered as CQPs. Minor changes in those QPs lead to possible quality deviations resulting in unacceptable and irreversible quality attributes. For instance, by a mechanism of non-enzymatic browning due to temperature abuse during filling/ storage, the product will change its color and flavor, and it cannot be returned to the original condition. Another example is microbial deterioration caused by microorganisms inside the product compounded with the influence of temperature and oxygen that results in viscous, slimy juice/ milk with a fishy smell and bad taste. It is clear that the changes are permanent and surely cannot be tolerated by the consumers.

Table 6. Identification of CQPs (based on the literature review)

Technological/ managerial factors (QPs)	T/M	Irreversible	Unacceptable for consumers	CQP?
Light	T	✓	✓	Yes
Pasteurization temperature	T	✓	✓	Yes
Pasteurization time	T	✓	✓	Yes
Filling temperature	T	✓	✓	Yes
Storage-distribution temperature	T	✓	✓	Yes
Storage-distribution time	T	✓	✓	Yes
Microbial load	T	✓	✓	Yes
Oxygen	T	✓	✓	Yes
Packaging material	T	✓	✓	Yes
Procedures	M	✓	✓	Yes
Production control	M	✓	✓	Yes
Storage-distribution control	M	✓	✓	Yes
Compliance of employees	M	✓	✓	Yes

3.1.5 Conceptual framework

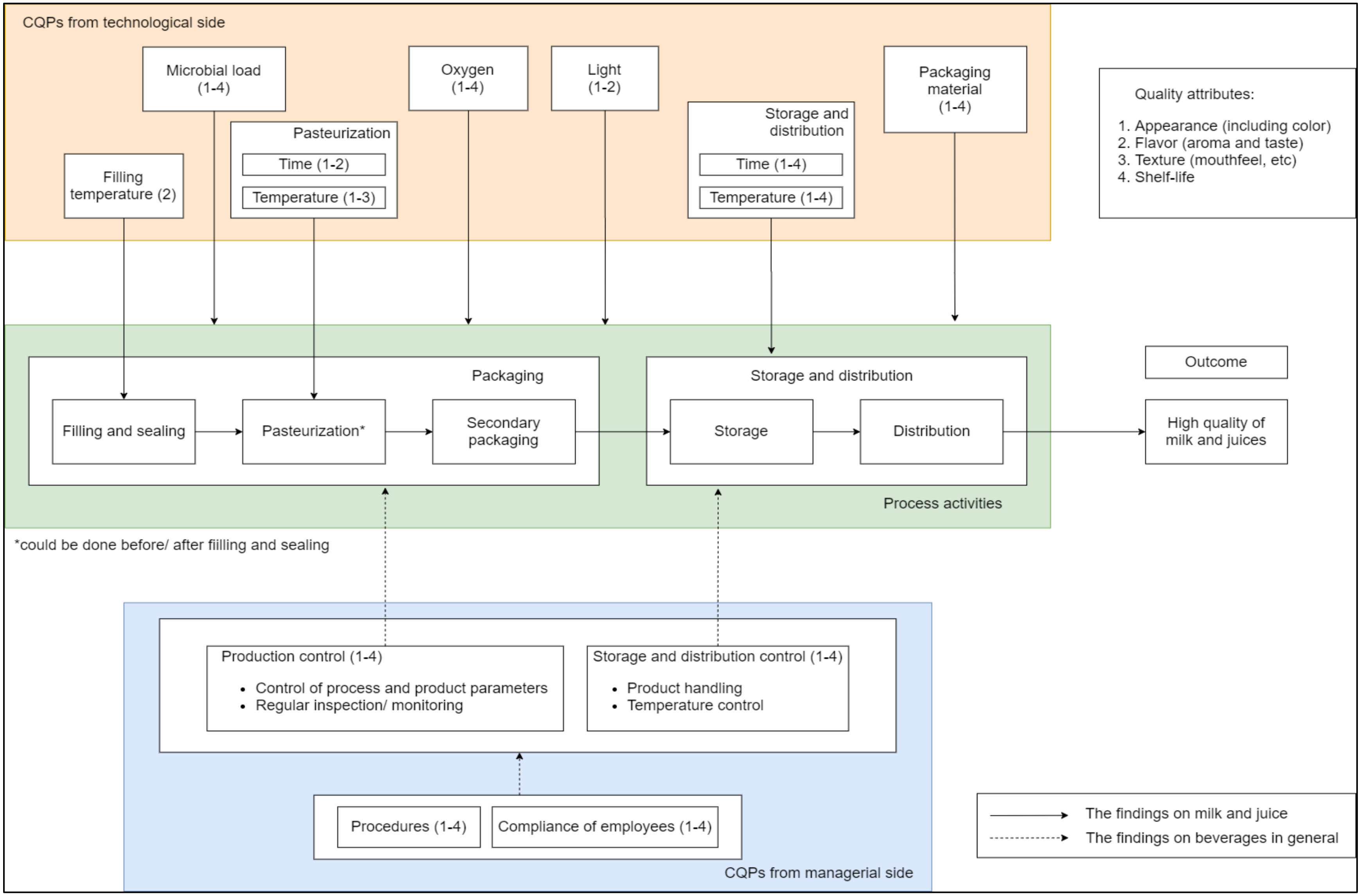

Figure 8. Conceptual framework of CQPs in milk and juices with conventional packaging (results of literature analysis)

Figure 8 visualizes the results of the literature analysis from step 2 to step 5 of the QACCP model. The flowchart starts with the process activities of milk and juices in conventional packaging from primary packaging until storage and distribution in general. The pasteurization step could be done after or before the product is filled into the container and then sealed. If the pasteurization is one step after filling and sealing, it becomes one of the relevant packaging process activities since the product has been already in contact with the packaging. The outcome of the overall processes is the high quality of milk and juices, which means good appearance, flavor, texture, and shelf-life without any quality deviations (spoilage, enzymatic browning, NEB, oxidation, degradation of compounds) occur.

As seen in Figure 8, in the technological point of view, there are 9 factors influencing milk and juices quality appearance, flavor, texture, and shelf-life in the whole process activities. They are microbial load, which can be affected by food dynamics (FD), along with oxygen, light, and packaging material, which are technological conditions (TC). The other TCs are explicitly found related to specific processes, and the influenced quality attributes are different between each factor. For instance, in the part of filling and sealing, the filling temperature will affect the taste and aroma of the product. The time of pasteurization is related to changes in appearance, flavor, while the temperature may lead to changes in appearance, flavor, and texture. Moreover, the time and temperature are possible to influence appearance, flavor, texture, and shelf-life as well in storage-distribution.

The figure also explains the managerial factors. The dashed line means that the analyzed factors are the general findings on beverages, not specifically for milk and juices. There are 4 relevant factors related to the people: compliance of the employees, which is human dynamic (HD), and procedures, production, and storage-distribution control are administrative conditions (AC). Appearance, flavor, texture, and shelf-life have the same chances to be affected by those M factors. In general, compliance of the employees and the appropriate procedures provided will influence the control activities either in the production process (as packaging is a part of it) or storage-distribution, and those quality points indirectly play a role in maintaining product quality. Since minor variation in all factors discussed may lead to the change in milk or juices that are irreversible and unacceptable for consumers, those are considered as CQPs.

3.2 Part B (CQPs of beverages in bio-based packaging)

3.2.1 Functional properties of bio-based materials (by literature review)

The search for this part resulted in 665 hits. After checking all the titles and abstracts, whether the publications met inclusion and exclusion criteria, 65 publications obtained. 6 publications (1 empirical study and 5 book chapters) were found suitable after analyzing the relevancy and removing the duplicates.

For beverage packaging, polylactic acid (PLA) and bio-polyethylene (PE) and its derivate, bio-polyethylene terephthalate (PET) are the bio-based materials that are commonly used, usually in the form of bottles or laminated cartons (Pandit, Nadathur, Maiti, and Regubalan, 2018; Rudnik, 2013; Coles and Kirwan, 2011). PLA is made from natural resources like corn starch, sugar beet, tapioca, and sugarcane (Pandit *et al.*, 2018; Coles and Kirwan, 2011), bio-PE is formed by the fermentation of sugarcane (Coles and Kirwan, 2011); whereas bio-PET contains 30-100% material from plants such as sugarcane, switchgrass, pine bark and corn husks (Copper, 2013). Table 6 explains more about the properties of these bioplastics.

Table 7. Functional properties of PLA and Bio-PE/PET

Bioplastics	Properties		References
PLA	Mechanical	Good mechanical properties (high modulus and strength) but low in toughness (but this characteristic could be improved by copolymerization), comparable to PET.	Rudnik, 2013.
	Moisture and gas permeability	Higher permeability of gas (O_2 and CO_2) and water vapor than PET.	Pandit *et al.*, 2018; Copper, 2013; Rudnik, 2013; Garcia and Lagaron, 2012.
	Flavor barrier	As packaging for orange juice, there is no d-limonene (main component of orange juice flavor) passed the PLA film, comparable to PET.	Rudnik, 2013; Coles and Kirwan., 2011.
	Thermal	Lower thermal resistance and stability compared than PET (Glass transition temperature= 50-60°C; melting point temperature= 130-180°C). However, in 2007, Purac modified PLA by blending with other polymers or incorporation with fillers, so the different version of it can survive until 175-190°C.	Copper, 2013; Rudnik, 2013; Garcia and Lagaron, 2012; Coles and Kirwan, 2011.
	Other properties	• When combined with nisin, the packaging performed a good antimicrobial activity as it could inhibit the growth of *L. monocytogenes* significantly. • It performs excellent printability due to high critical surface energy as the result of high polarity. It also shows high sealability. • Resistant to fat and oils. • PLA is compostable, not by home composting, but should be facilitated by the composting machines from specific industries. • It has a major problem of brittleness.	Pandit *et al.*, 2018; Copper, 2013; Rudnik, 2013; Garcia and Lagaron, 2012; Coles and Kirwan, 2011.
Bio-PE/PET	Similar chemical, physical, and mechanical properties to conventional PE/ PET. Conventional PE • Heat sealable. • It could be built into tough and strong films. • It can be considered as an excellent barrier to moisture. • Compared to other plastics, PE performs a low barrier to O_2, CO_2, fats, and oils, but the increase of density can modify those barrier characteristics.		Pandit *et al.*, 2018; Copper, 2013; Coles and Kirwan, 2011.

Bioplastics	Properties	References
	• Lower resistance to heat than other packaging plastics (melting point temperature = 120ºC, can be increased by higher density). • PE is commonly combined with paperboard to be used as liquid food containers. • It is not compostable. Conventional PET • It shows high mechanical strength, including puncture resistance. • Higher resistance to heat (melting point temperature = 260ºC) → ideal for heat applications. • Low permeability of gases and water vapor. • It is used for many packaging applications related to food and beverages, such as soft drinks, mineral water.	

In addition to PLA, a study by Haugaard, Weber, Danielsen, and Bertelsen (2003) compared the performance of conventional packaging, namely high-density polyethylene (HDPE) and polystyrene (PS) with PLA, in protecting unpasteurized orange juice from the changes during storage at 4ºC for 14 days. It is found that the color changes in orange juice packaged with PLA and PS were lower than HDPE. Ascorbic acid degradation was observed lower in PLA rather than HDPE and PS. About scalping of limonene (primary aroma flavor in orange juice), juice packaged with HDPE performed a high degree of scalping whereas, in PLA and PS, there was no indication of scalping could be detected. Additionally, the unpasteurized orange juice in PLA, PS, and HDPE packaging showed undesirable aroma after 7 days of storage due to spoilage by yeasts and molds. The authors concluded that certain bio-based material (PLA) can be used to contain beverages since it is comparable to petroleum-based packaging.

The use of PLA packaging to protect products in a short time is the agreement with publications by Copper (2013) and Coles and Kirwan (2011). PLA is mostly used for packaging fresh/ short shelf-life products without any special barrier requirements. For example, in mass production, PLA is successfully used to contain yogurts. Its weaknesses, such as low-temperature stability and brittleness, are not critical since the products require cold chains and the brittleness could be decreased by the additives, respectively. Furthermore, the mentioned weaknesses of PLA, along with poor barrier properties compared to conventional plastics, contribute to its low processability and applicability. Hence, the use of other materials such as PE or PET is more suggested for the products where high-temperature processing and high barrier properties are required.

As mentioned before, the beverage is possible to be packaged in the form of laminated or multi-layered cartons. The layers used for packaging products depend on the shelf-life, product properties, and the treatment of the products. Double-side PE with a paperboard is enough for fresh/ short shelf-life products like milk with the cold distribution. The aluminum layer should be added for protecting products with a longer shelf life, which is distributed in ambient temperature, for the product that involves hot filling, and for juices. The arrangement of the lamination may consist of PE/paperboard/PE/aluminum foil/PE (Coles and Kirwan, 2011).

3.2.2 Information related to milk and juices in bio-based packaging (by expert interviews)

From 35 companies that have been contacted, 7 experts from those companies were committed to help the research. During data collection, the experts gave a lot of insights from different perspectives. After processing the interview data, the interview results in three parts were reported below.

Part 1 - The change of product packaging from conventional to bio-based materials

This part emphasized the journey of switching product packaging into bio-based ones, including the background, changes, and challenges that companies had to deal with. 5 of 6 milk and juice companies started implementing bio-based packaging in around 2017 and 2018 after related trials and tests, whereas the company of Expert A implemented this new packaging earlier in 2015. It also can be concluded that such bio-packaging implementation did not take much time as the companies were able to sell their products packaged with new materials to the market in the same year after the decision to change. Moreover, Expert G, whose company offered more sustainable packaging to its customers since 2014, confirmed that usually, the time needed for this project was a maximum of one month.

As seen in Table 8, there was a consensus among all experts concerning the reason for using bio-based packaging. 7 of 7 experts suggested that the change into more sustainable packaging was a real action regarding environmental concerns. The additional motives were because the companies were encouraged to support the packaging company’s projects, and there was an increasing consumer demand for more eco-friendly products.

Speaking of the major changes in the company when trying to implement bio-based packaging, 3 milk and juice companies experienced little to no changes in the processes, equipment, quality control activities, and so on. At least 3 of 7 experts stated the major difference was related to the packaging design as those companies aspired to present their sustainability commitment there. Could not recall anything highly altered, expert A answered the change in documentation system was considered the most significant change. However, even though most of the experts from milk and juice companies admitted the process of changing packaging materials was relatively straightforward, a company where Expert C works still had to invest new lid applicator machine to be fitted with the new form.

It can be noticed from Table 8, 4 of 7 experts revealed that their companies did not find any challenges since everything went smoothly. However, there were various challenges found involving many aspects such as the cost of materials, the limited choice of bio-based alternatives (e.g., the renewable composition in bio-PET in the market was still around 33%), and marketing and branding (the consumers tend to choose products with 100% bio-based materials).

Table 8. Overview of interview results

Questionnaire	Answers						
	Expert A	Expert B	Expert C	Expert D	Expert E	Expert F	Expert G
Part A. The change of product packaging from conventional to bio-based materials							
Decision to change	2014	2018	2017	2017	2018	2018	2014
Reason	Sustainability	Sustainability & consumer demand	Sustainability & support from the packaging company	Sustainability	Sustainability	Sustainability & support from the packaging company	Sustainability
Start implementation	2015	2018	2017	2018	2018	2018	2014
Major change	Documentation to the file system	None	Packaging design & lid applicator machine	None	None	Packaging design	Packaging design
Challenges	Money/ material cost	Limited alternatives for plastics	Branding	None	None	None	None
Part B. Bio-based materials for milk/ juices packaging							
Product	Milk, yogurt, cream	Milk	Milk, yogurt	Milk	Fruit juices	Fruit juices	Milk, yogurt, fruit juices
Packaging form	100% bio-based gable top carton packaging	Gable top carton packaging	100% bio-based gable top carton packaging	98% bio-based milk jug	Carton packaging	80% bio-based gable top carton packaging	Up to 100% bio-based gable top carton packaging
Type of bio-plastic	Bio-based PE	Bio-based PE	Bio-based PE	Bio-based PE	Bio-based PE	Bio-based PE	Bio-based PE
In which part?	All plastic layers & lid	Outer plastic layer & lid	All plastic layers & lid	Entire packaging (body, sleeve, lid)	All plastic layers & lid	Outer plastic layer & lid	All plastic layers & lid
Properties, including strengths (+) & weaknesses (-)	(+) = Conventional PE (+) Reduce the use of natural resources (-) Price	Similar to conventional PE	(+) = Conventional PE (-) Complaint about low degradability	Similar to conventional PE	*(No information from the expert)*	*(No Information from the expert)*	(+) = Conventional PE (+) Reduce the use of natural resources (+) Recyclable (-) Price (-) Not biodegradable

Questionnaire	Answers						
	Expert A	Expert B	Expert C	Expert D	Expert E	Expert F	Expert G
Part C. Product quality with bio-based packaging							
Are there any differences in quality points to be controlled (before and after implementation)?	No	No	No	No	No	No	No
Experienced/ reported quality deviations	None	None	None	None	None	None	None
Factors influencing the quality of the product in bio-based packaging	Similar to conventional ones: -Packaging material -Product properties -Sealing temperature and time -Cold chain (storage-distribution temperature-time) -Training of the employees -Hygiene -Procedures	Possibly similar to conventional ones → can be assured by the good quality of packaging material	Similar to conventional ones: -Product properties -Sealing temperature and time -Packaging material -Manufacturing cost (not critical) -Incoming material control	Similar to conventional ones: -Light -Training of the employees -Procedures	Possibly similar to conventional ones	Similar to conventional ones: -Sealing temperature and time -Packaging material -Training of the employees, especially the HACCP program	Possibly similar to conventional ones

Part 2 - Bio-based materials for milk/ juices packaging

It was a part of discussing the bio-based materials used for packing milk and juice products. 6 of 7 companies chose carton packaging form, which consisted of different functional layers, particularly paperboard, plastics, and could be added with the aluminum layer depending on product properties and shelf-life proposed. Solely, the company of Expert D used a form of the milk jug. 7 of 7 experts indicated that bio-based PE was utilized as an alternative component for the regular plastic part. 5 of 7 experts revealed that the application of bio-based material had already been in whole plastic parts of the packaging, while the company of Expert B and F used it for the lid and outer layer. Expert G disclosed the preference of the company to bio-based PE over PLA since PLA was biodegradable. It brought to at least two reasons. Currently, this packaging company only focused on the materials that could be used continually after the recycling process. Furthermore, it seemed to be quite risky and vulnerable for PLA to be used as a liquid container, especially when the products were not frozen, and the packaging-product contact was quite lengthy.

Obtained from the 4 of 7 experts, the properties of bio-based PE and conventional PE were similar. It was assumed as one of the strengths besides the sustainability aspects: the ability to be recycled along with reducing the use of natural resources and CO_2 emission. The weaknesses reported were linked to the high price and a presumption about the low degradability of bio-PE. As shown by Expert G during the interview, Figure 9 illustrates clearly why plastic PE from petroleum and renewable resources such as sugarcane were alike in terms of the overall characteristics and later, the performances. They just differed in terms of feedstocks.

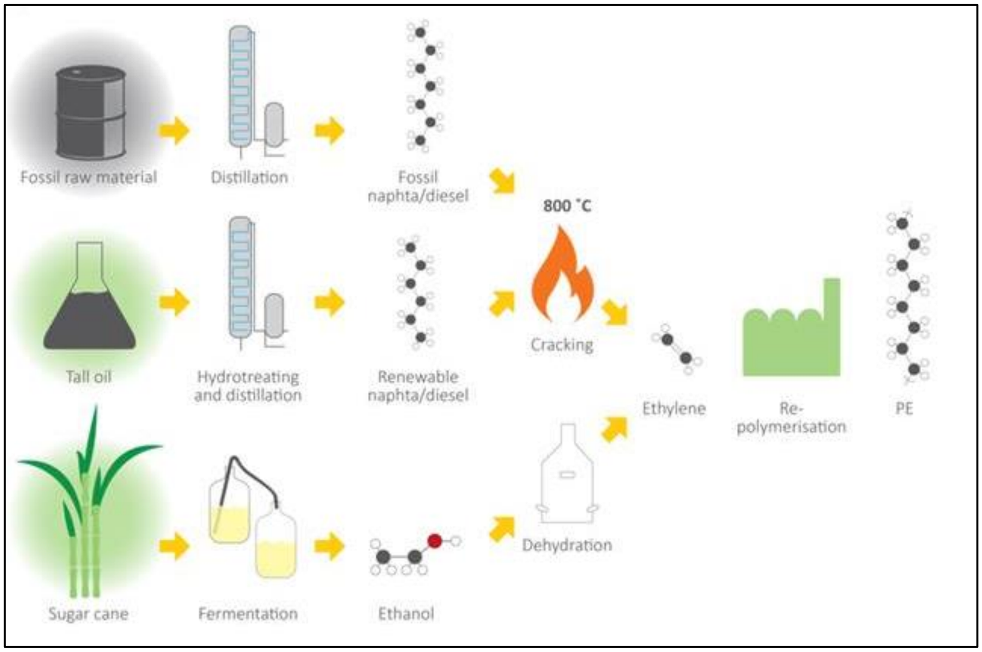

Figure 9. Plastic PE from non-renewable and renewable resources

Part 3 - Product quality with bio-based packaging

Information regarding the quality of milk and juices packaged with bio-based materials and the control activities was further described in this section. 7 out of 7 experts agreed that the additional or extra quality control for products with bio-based packaging was not needed. Before the routine implementation, the company would make sure the packaging suppliers delivered the high-quality packaging materials (covered in specifications and contracts) along with conduct running tests in the production area, product stability tests, and quality check when needed. Since the overall performances of bio-based packaging were identical to conventional ones, the companies handled the products in the same way. Concluded from 7 of 7 experts, the packaging with bio-PE layers was highly feasible to be implemented for at least three reasons: compared to regular packaging, product quality and shelf-life remained the same, and there was no increased work for the employees.

For quality control, just like regular products, incoming raw and packaging materials were checked at the entry. During whole processing, milk and juice companies would normally conduct daily chemical, physical, microbiological, and sensory tests for the products, including temperature and hygiene control. Relating to packaging, the leakage test, along with primary and secondary visual inspection, were parts of the routines.

In addition, through the implementation, 7 of 7 experts revealed that there was no product quality deviation experienced so far. Expert C mentioned that the change in milk taste and aroma depending on the materials could happen, but that was not the case for this company. Microbial spoilage and light-induced oxidation were additional possible quality deviations told by Expert D, but the occurrence of those deviations was minor if proper measuring and control checks for whole attributes were in place.

Regarding the factors that influenced the product quality, the pattern of the answers given could not be seen clearly, even though 7 of 7 experts expressed that the factors affecting quality attributes in milk and juices tended to be comparable for both packagings respecting they had similar properties. The detail descriptions of technological-managerial factors and the CQPs based on expert interviews are displayed below.

Table 9. Identification of CQPs (based on expert interviews)

<table>
<tr><th>Factors (QPs)</th><th>T/M</th><th>Descriptions</th><th>CQP?</th><th>Expert(s)</th></tr>
<tr><td>Light</td><td>T</td><td>It depends on the product properties and the type of packaging used. For milk in entire plastic packaging without a full light barrier (partially transparent/ less opaque), especially during storage, the intensity of light can damage the fat milk called oxidation. The perceivable direct impact is chemical/ “plastic” taste.</td><td>Yes</td><td>D</td></tr>
<tr><td>Sealing temperature</td><td>T</td><td rowspan="2">It guarantees that the package is closed. The product is possible to have low quality if it is not well-sealed since oxygen, light, microorganisms, and particles</td><td>Yes</td><td rowspan="2">A, C, F</td></tr>
<tr><td>Sealing time</td><td>T</td><td>Yes</td></tr>
</table>

Factors (QPs)	T/M	Descriptions	CQP?	Expert(s)
		can enter the packaging. It is also related to sealing machine optimality conditions.		
Product properties	T	The nature of the products, such as acidic, watery characteristics, and nutrients, will influence the quality. For example, milk is susceptible to spoilage (perishable) since it provides a supportive medium for microbes to grow.	Yes	A, C
Packaging material	T	In the context of both primary and secondary packaging, it should have the ability to protect products from external conditions and should be safe for food contact (inert). Hence, quality deviations can be anticipated.	Yes	A, B, C, F
Storage and distribution temperature	T	Due to inappropriate time-temperature, the product tends to be unstable, concerning the product properties itself.	Yes	A
Storage and distribution time	T		Yes	
Training of the employees	M	Training will increase the employees' knowledge, skills, awareness, and compliance and give a better understanding of the business process and maintaining product quality, particularly training about quality standards and HACCP program.	Yes	A, D, F
Procedures	M	It is critical to provide updated, understandable, and complete procedures. Besides supporting the operators to do their jobs correctly, the procedures help ensure consistency between one process and another.	Yes	A, D
Hygiene	M	The hygienic production process and personnel prevent the microbial load in production areas. Especially in the packaging process, it helps to prevent post pasteurization contamination (PPC).	Yes	A
Incoming material control	M	Since high-quality products start from high-quality incoming materials, everything should be checked (supplier documents, specification details). The decision to release materials should be strictly based on specifications. It is important to ensure the raw material of batch A, B, etc. have the same quality.	Yes	C
Manufacturing cost	M	For products with limited margin, normally companies will deal with costly material, everything in the process should be efficient (labor, running time, machine – electricity, etc.). On the other side, product quality should be maintained.	No	C

3.2.3 Conceptual framework

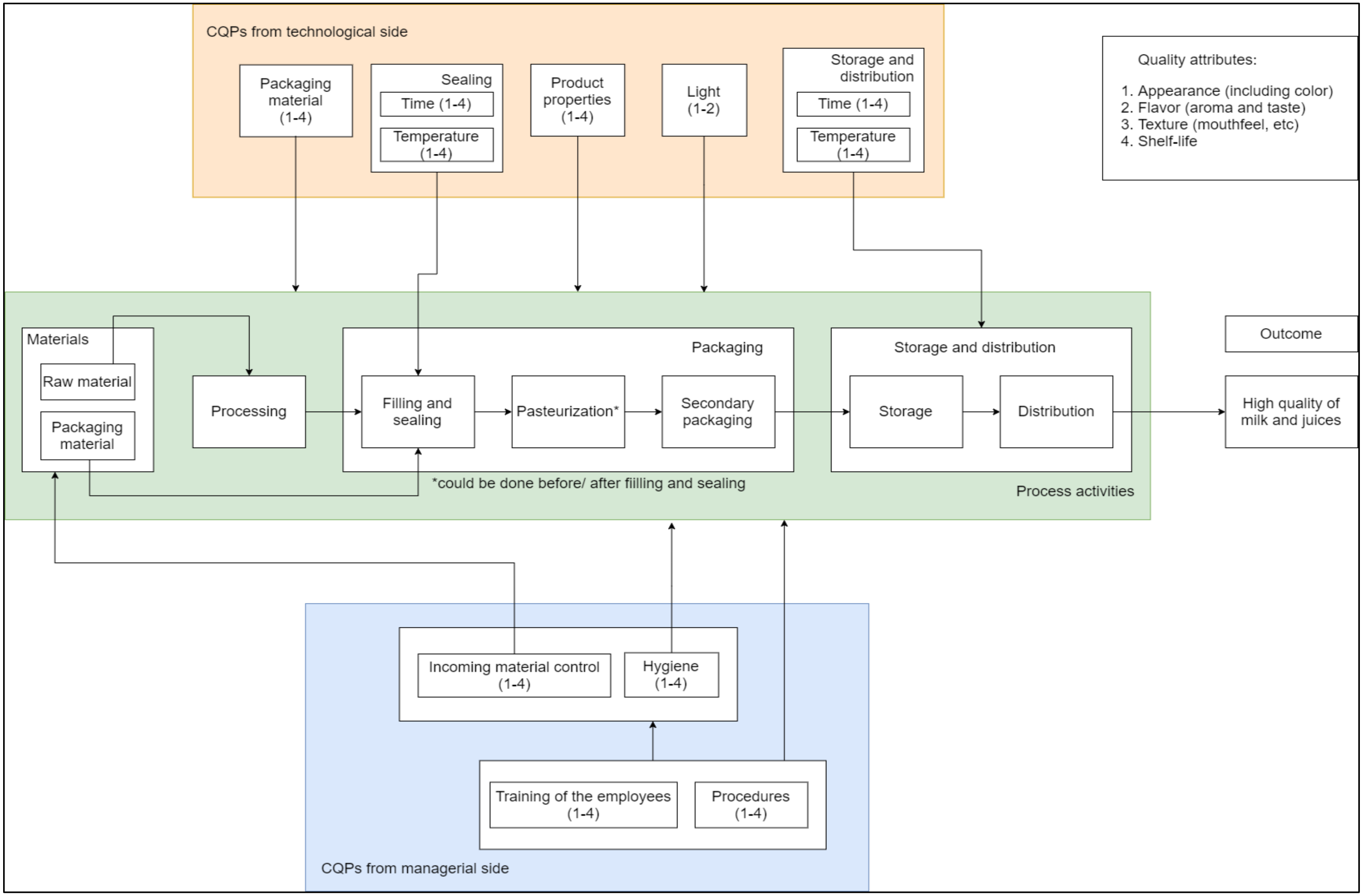

Figure 10. Conceptual framework of CQPs in milk and juices with bio-based packaging (results of expert interviews)

Figure 10 displays the result of interviews and their relationship to process activities and quality attributes. As a new insight gained through the expert interviews, even though the research focus is from the packaging process, the incoming material activities should also be included since it is a selection entrance for the right packaging materials to be used to contain and protect the products. Thus, the flowchart of process activities is extended. The materials are then processed and packaged before entering the storage and distribution phase. As already defined before, the quality attributes that should be maintained are appearance, flavor, and texture. Those sensory attributes can be related to shelf-life since keeping product shelf-life also means keeping the desired sensory properties of the products.

There are 7 technological factors that, from now on, are identified as CQPs since their influence on milk and juices may lead to irreversible and unacceptable changes for consumers. In whole process activities, packaging materials and product properties can affect appearance, flavor, texture, and shelf-life, whereas light only gives effect on appearance and flavor. Time and temperature will stimulate changes in product quality, particularly in the process of sealing and storage-distribution.

4 CQPs of managerial-related aspects are determined: training, procedures, hygiene, and incoming material control. All managerial CQPs will influence milk and juice appearance, flavor, texture, and shelf-life as people have an essential role in the manufacturing process. Training of the employees, along with procedures, has effects on the product quality in entire process activities also on hygiene and incoming material control. In addition, hygiene might influence the determined sensory and shelf-life quality attributes in whole processes as well, whereas incoming material control is purposely for incoming material activities.

3.3 Result analysis

This section integrates findings from the literature and expert interviews to be able to identify CQPs in milk and juices packaged with bio-based PE plastic.

3.3.1 Bio-based packaging

From the literature analysis, it is discovered that PLA, bio-based PE, and PET can be applied for beverage packaging. Based on expert interviews, all companies where the experts work used bio-based PE for their milk and juices.

With PLA, the product should have a shorter shelf-life than the conventional material and should be stored cold. Its biodegradability and brittleness along temperature instability make it quite vulnerable for beverages such as milk and juices. Consequently, it may contribute to product leakage due to accidental collision, or it is possible to melt because of hot-filling or fluctuating storage temperature. Moreover, the barrier properties of PLA still need further improvements to assure milk and juice quality.

Table 10. Findings of bio-based packaging from literature review and expert interviews

Findings	Bio-based plastic packaging material for beverages	
	Based on the literature review	**Based on expert interviews**
Similar	Bio-based PE	Bio-based PE
Different	Bio-based PET	
	PLA	

There is increasing use of bio-based PE and PET in the market for accommodating sustainability issues. According to 7 of 7 experts, their companies applied the beverage packaging, which consisted of a bio-based PE layer for conventional PE replacement, in the form of multi-layered carton packaging and entire plastic packaging. In carton packaging case, bio-based PE is used for product protection, leakage prevention, and adhesive between each layer, for instance, paperboard and aluminum. Bio-based PE, which has similar characteristics to the regular PE plastic, may not fulfill all functional requirements for beverage packaging, but here, its inability is covered by the combination of other layers. It is possible to use bio-based PE solely for packing short shelf-life products like milk, but the factor of light should be strictly controlled (mainly for a highly transparent container) as normally, the light barrier comes from solid-colour/ opaque packaging and aluminum part.

Not much information can be obtained related to bio-based PET. It is in line with a statement from Expert B: for PET, there is not a 100% bio-based version available on the market, only 33% at this moment. There are a lot of developments ongoing, but it will take a while until they are developed and ready to be used at large scale.

3.3.2 Possible quality deviations (specific research question 1)

Literature analysis determines 5 possible quality deviations in milk and juices with conventional packaging, which are: enzymatic and non-enzymatic browning (NEB), oxidation, microbial spoilage, and degradation of compounds. Meanwhile, oxidation, microbial growth, and flavor scalping were the possible quality deviations obtained from expert interviews. It can be noticed in Table 11 that microbial spoilage and oxidation are similar results from the literature and expert interview method.

Table 11. Findings of possible quality deviations in milk and juices from literature review and expert interviews

Findings	Possible quality deviations in milk and juices	
	Conventional packaging (based on the literature review)	**Bio-based packaging (based on expert interviews)**
Similar	Microbial spoilage	Microbial spoilage
	Oxidation	Oxidation
Different	Enzymatic browning	Flavor scalping
	Non-enzymatic browning (NEB)	
	Degradation of compounds	

Considering conventional PE and bio-based PE are similar in properties, milk and juices that are packaged with these both packagings are possible to experience the same quality deviations. However, as seen in Table 11, there is a gap between the results from two methods. Here are 3 reasons for the gap.

1. The data collection for the possible quality deviations relied on questionnaires with the open questions instead of confirmation questions, so that the results obtained from expert interviews could not cover all findings from literature analysis.

2. 5 of 7 experts did not mention any possible quality deviations considering there was no quality deviation found or reported to their companies when bio-based packaging is used so far. According to Expert B, no quality deviations experienced can be related to good packaging material quality, along with proper product handling and control. Typically, companies in collaboration with packaging suppliers might have put a considerable effort into assuring the quality of packaging materials to be able to give full protection to the products before start using it. The packaging materials were also expected to be well-performed, proven by the same specification details and quality test results as the regular ones. Furthermore, inevitably, good product handling and control play a significant role in reducing the risks of quality deviations.

3. Expert C mentioned flavor scalping, whereas Expert D mentioned oxidation and microbial spoilage, even though those were not the real case from their companies. The possibility why flavor scalping, oxidation, and microbial spoilage were mentioned is those possible quality deviations are unavoidable even though high-quality materials and proper quality control are all set.

Expert C defined flavor scalping as a phenomenon where the food flavor compounds are absorbed into the packaging material or vise versa, affecting the flavor quality negatively. Apart from the influence of temperature or packaging and product properties, it will generally occur in products with extended shelf-life, so there is prolonged contact between packaging and product. Thus, the nature of product and packaging contact brings flavor scalping as one of the possible quality deviations.

Oxidation and microbial spoilage as possible quality deviations were obtained from Expert D, who works in a fresh milk company. The milk is not added with preservatives and packaged with semi-opaque milk jug. Without preservative agents, microorganisms have an opportunity to grow and spoil the product by degrading or releasing compounds. It is also supported by a high water content and nutritional value of milk. About oxidation, Expert D stated that light-induced oxidation is very common, causing off-flavor known as plastic/ chemical taste. In this case, it could be due to the packaging form, which is unable to protect the milk completely. As known, the full light barrier comes from the non-transparent container with a solid color. That is why oxidation and microbial growth are possible to happen even though quality control is in place. Those quality deviations are found through literature analysis as well, with the possibility of happening to both beverage products.

It is obvious from Table 11 that there are three factors that are different between both methods: degradation of compounds, enzymatic and non-enzymatic browning. Degradation of compounds was probably not mentioned because this type of deterioration can happen simultaneously or consecutively with other deteriorations. For instance, the light will induce milk oxidation and degradation; microbial growth may lead to the degradation of compounds. Regarding enzymatic and non-enzymatic browning, which are not noticeable, these deviations are mainly because of the temperature abuse. Most likely, as indicated by Expert B, the companies apply proper product handling and temperature control, especially during filling and storage. Hence the occurrence of enzymatic and non-enzymatic browning can be highly minimized. Specifically, for juice products, those deviations may also be reduced with the help of ascorbic and citric acid composition, acting as natural anti-browning agents.

Overall, combined from both methods, the possible quality deviations in milk and juices with bio-based PE packaging are flavor scalping, oxidation, microbial spoilage, degradation of compounds, enzymatic and non-enzymatic browning.

3.3.3 T-M factors (QPs) influencing quality attributes of milk and juices in bio-based PE packaging and related CQPs (specific research question 2 and 3)

Literature shows a total of 13 factors that can influence milk and juice quality. In detail, there are 9 technological factors (light, packaging material, storage-distribution temperature, storage-distribution time, pasteurization temperature, pasteurization time, filling temperature, oxygen, and microbial load) and 4 managerial factors (procedures, compliance of employees, production control, and storage-distribution control). Expert interviews resulted in 12 factors consisting of 7 technological factors and 5 managerial factors. The T factors are light, packaging material, storage-distribution temperature, storage-distribution time, sealing temperature, sealing time, and product properties. M factors include procedures, hygiene, training of employees, incoming material control, along with manufacturing cost (not identified as CQP). As seen in Table 12, both methods obtained 4 similar findings: 1 managerial factor and 3 technological factors, including light.

Light is a kind of particular case here. Expert D, whose company used whole plastic milk jug, expressed that the light could cause light-induced oxidation. However, interpreted from Expert A, B, C, and F, the influence of light was possible to be reduced by proper sealing and storage-distribution control, along with mainly applying packaging materials with sufficient light barrier. Milk and juice produced by companies of those 4 experts were packed with carton packaging. Typically, it has printed paperboard and aluminum layer (for products which needed extra protection) as the light barrier. Accordingly, it can be assumed that the light factor tends to be a factor that influences product quality and CQP if the packaging material has a low light barrier.

Table 12. Findings of T-M factors influencing the quality of milk and juices and CQPs from literature review and expert interviews

Findings	Factors (QPs) in milk and juices + CQPs					
	Conventional packaging (based on the literature review)			Bio-based packaging (based on expert interviews)		
	Factors (QPs)	T/M	CQP	Factors (QPs)	T/M	CQP
Similar	Light	T	✓	Light	T	✓
	Packaging material	T	✓	Packaging material	T	✓
	Storage-distribution temperature	T	✓	Storage-distribution temperature	T	✓
	Storage-distribution time	T	✓	Storage-distribution time	T	✓
	Procedures	M	✓	Procedures	M	✓
Different	Pasteurization temperature	T	✓	Sealing temperature	T	✓
	Pasteurization time	T	✓	Sealing time	T	✓
	Filling temperature	T	✓	Product properties	T	✓
	Oxygen	T	✓	Hygiene	M	✓
	Microbial load	T	✓	Training of employees	M	✓
	Compliance of employees	M	✓	Incoming material control	M	✓
	Production control	M	✓	Manufacturing cost	M	x
	Storage-distribution control	M	✓			

From Table 8 and Table 12, even though 7 of 7 experts agreed the factors influencing quality attributes in both conventional and bio-based packaging were comparable (no changes/ differences in quality points to be controlled) due to the same functional properties of plastic PE contained, the gap between the findings can be noticed clearly. It is because of 4 possibilities:

1. Confirmation questions were not used to collect data from experts. It might result in a different number of findings as the experts did not mention the other factors found through the literature review.
2. The findings of the literature review were maybe not comprehensive enough. As an example, sealing temperature-time was not seen even though their impact on packaged beverages was rational.
3. Both methods used slightly different perspectives to discuss how a factor can influence product quality. In the case of compliance-training or microbial load-hygiene, they referred to the same meaning in the end.
4. The factors found in literature analysis were not applicable or relevant to their companies. For instance, the pasteurization time-temperature was not the case for the companies that did not include in-pack pasteurization in their process. Further about reasoning numbers 3 and 4 are explained below.

As observed in Table 12, it is possible to integrate the factors considering two or more factors that can influence each other, and the contribution of two or more factors may lead to more significant changes in milk and juice quality attributes. The following is the integration of the different findings together with the possible analysis of why those technological or managerial quality points were not mentioned.

Filling temperature

Based on literature search, filling temperature is an important factor that should be controlled. However, this factor was not mentioned when asking the experts. It is probably because the experts did not perceive the influence of this factor so far. In total 2 juice companies and 4 milk companies, 3 of 6 companies use cold-filling method, 2 of 6 companies use an aseptic filling, and 1 company use both types of filling. In cold-filling, the product is filled to the packaging at a very low temperature (around 2-3^{o}C), whereas aseptic filling requires heating to reduce the microbial content but only for a very short time (0,5-1,5 minutes). Hence, the product quality is still better preserved, and the thermostability properties of the packaging are not affected as well. Nevertheless, the filling temperature can be determined as CQP for this case since minor variation in temperature and time will indeed affect the flavor quality of the product, as discussed earlier in the section of literature results.

Pasteurization temperature - time

Concerning pasteurization temperature-time, as mentioned earlier in this section, it seems to be not relevant for 6 of 6 companies because, in this case, their product will be pasteurized first before packaged while from the literature method, the factor of pasteurization becomes important if the product undergoes an in-pack pasteurization process. It is decided to identify pasteurization temperature-time as CQPs with specific conditions. If the in-pack pasteurization is a part of the manufacturing process, then pasteurization temperature-time may be a relevant factor and also CQP.

Oxygen – Sealing temperature - time

For oxygen, maybe the companies did not have a specific oxygen control as indicated by Expert C. Expert C then emphasized that its existence could be lowered by functional properties of packaging materials used, which should be in a very low permeability of gases and moisture. Generally, plastic and aluminum materials can fulfill this requirement. Moreover, the presence of oxygen is possibly reduced by controlling the sealing process. Improper sealing temperature and time will decrease the product quality attributes and shelf-life since even the slightly opened container can act as an entrance for unintended external elements (light, oxygen, particles, microorganisms). Therefore, sealing temperature-time is one of the CQPs. However, oxygen is included to be a technological factor and later, CQP, only if the packaging has medium to high permeability to gases.

Microbial load – Hygiene – Product properties

Literature analysis finds microbial load as one of the factors and later is also determined as CQP. Practically, the microbial load is closely related to hygiene and product properties. Hygienic processes, equipment, and people will influence the microbial load in the product. In packaging activities, as the next step after normal pasteurization, the hygiene will be more crucial considering the risks of post-pasteurization contamination (PPC) as stated by Expert A. Furthermore, variable product properties of products such as nutritional value, pH, sugar content, and water content, can support microorganisms to grow and survive. Thus, it is decided to include microbial load as the relevant CQP together with hygiene and product properties.

Compliance of the employees – Training of the employees
There is a connection between the compliance and training of the employees. 3 of 7 experts discussed that the training helps to increase employees' knowledge and skills and may contribute to the increase of compliance to procedures and quality standards once they understand why doing things in the right way is very important. During a training session, the concept of compliance can be introduced to explain that humans are dynamic and hard to control.

Incoming material control – Production control – Storage-distribution control
Incoming material control as an additional insight obtained from Expert C during the interview seems to complete the quality control in the milk and juice manufacturing process. Even though it is demarcated to focus on the packaging process, incoming material control, as part of supply control, checks the packaging material used for keeping product quality. Sealing temperature-time and storage-distribution temperature-time found through expert interviews imply that the companies are applying control of those activities. So, combined from two methods, incoming material control (supply control), production control, and storage-distribution control are the other CQPs from the managerial point of view.

Manufacturing cost
A product with high quality is commonly related to high manufacturing costs. Therefore, as one of the people and administrative quality points, including manufacturing cost as a factor seems to be logical as companies generally must deal with efficiency and productivity while maintaining quality. Linking to it, milk and juice companies may be able to produce a bit low-quality product due to limited manufacturing cost, but its fluctuation does not necessarily lead to changes in the products, which is either irreversible or unacceptable. Since it does not meet the criteria, the manufacturing cost is not identified as CQP.

To sum up, the quality points which give effects on milk and juice quality attributes are light, packaging material, storage-distribution temperature-time, filling temperature, pasteurization temperature-time, sealing temperature-time, oxygen, microbial load, product properties, procedures, hygiene, compliance of the employees, training of the employees, manufacturing cost, along with control of incoming material, production, and storage-distribution. From all quality points recently discussed, only manufacturing cost that is not identified as CQP.

3.3.4 Conceptual framework

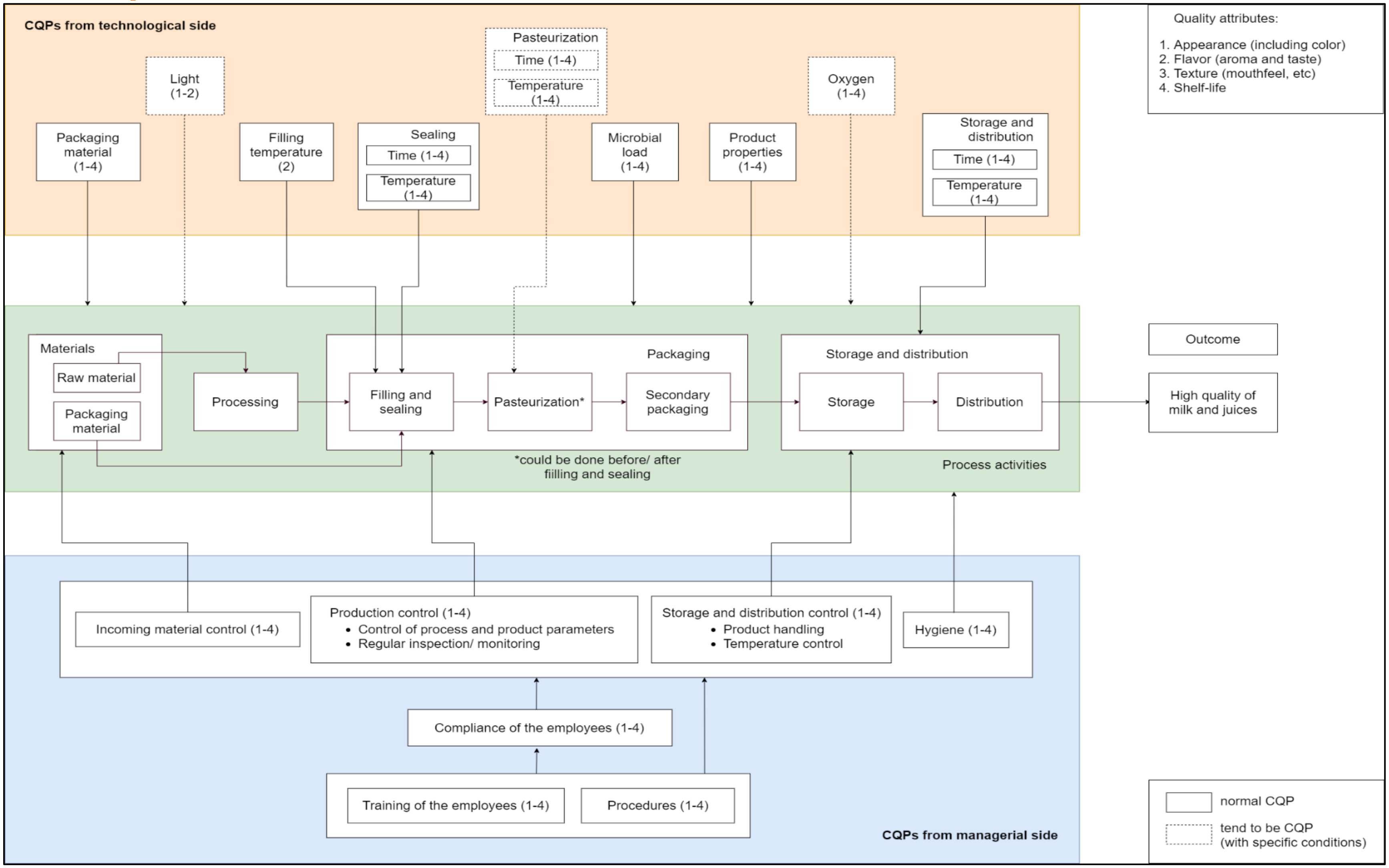

Figure 11. Conceptual framework of CQPs in milk and juices with bio-based PE packaging (integrated from literature and expert interviews)

Integrated from Figures 8 and 10, Figure 11 shows a conceptual framework of CQPs in milk and juices with bio-based PE packaging. There are 12 CQPs from the technological point of view and 7 CQPs from the managerial point of view. Dash square line is used to distinguish the real CQP and a factor that tends to be the CQP if there is a specific condition following (conditional CQP). As seen in Figure 11, in the box of technological CQPs, a total of 4 conditional CQPs are presented in the flowchart. Light and oxygen tend to be CQPs if the packaging materials used are considered to have a low barrier to those external conditions. Meanwhile, pasteurization temperature and time may be the relevant CQPs if in-pack pasteurization is chosen for the process. Light will influence the appearance and flavor of milk and juices. Oxygen, along with pasteurization temperature-time, will affect appearance, flavor, texture, and shelf-life. Besides that, the methods also resulted in other 8 technological CQPs, which are all relevant for milk and juices in bio-based packaging without any requirements. Packaging material, product properties, microbial load, sealing temperature-time, and storage-distribution temperature-time are possible to affect appearance, flavor, texture, and shelf-life, while variation in filling temperature may lead to flavor changes.

7 managerial CQPs found are likely to influence milk and juice appearance, flavor, texture, and shelf-life direct/ indirectly considering people intervention in the process is inevitable. Training of the employees, together with procedures, can influence the compliance of the employees, hygiene, and control of incoming material, production, and storage-distribution. Compliance of the employees also can affect the execution of those 4 managerial CQPs mentioned earlier. Hygiene is critical in whole process activities, whereas incoming material control, production control, and storage-distribution control are critical for each specific process activity.

4 Conclusions, limitations, and recommendations

This part explains the conclusions of the research along with limitations and recommendations for further study.

4.1 Conclusions

1. *What are the possible quality deviations in packaged beverages with bio-based materials, regarding sensory and shelf-life quality attributes?*

   Possible quality deviations in packaged milk and juices with bio-based materials obtained from literature analysis and expert interviews are enzymatic browning, non-enzymatic browning (NEB)/ Maillard reaction, oxidation, microbial spoilage, degradation of compounds, and flavor scalping. So far, all experts revealed that their companies did not experience any quality deviation in their milk and juice products because of their commitment to apply proper quality control and providing more sustainable packaging materials which also have good functional properties like regular ones.

2. *What are the technological and managerial factors influencing sensory and shelf-life quality attributes of packaged beverages with bio-based materials?*

   Integrated from literature analysis and expert interviews, there are 12 technological factors and 8 managerial factors determined in this research. The technological factors include light, packaging material, storage-distribution temperature and time, filling temperature, pasteurization temperature and time, sealing temperature and time, oxygen, microbial load, and product properties. Light and oxygen tend to be the relevant factors if the packaging has limited protection to light and oxygen. Pasteurization temperature and time are included to be a technological factor if the companies apply in-pack pasteurization.

   In relation to milk and juice quality attributes, packaging material, product properties, microbial load, sealing temperature and time, storage-distribution temperature and time, pasteurization temperature and time, and oxygen can influence appearance, flavor, texture, and shelf-life. Filling temperature can affect the flavor, whereas light can change appearance and flavor.

   The managerial factors include procedures, hygiene, compliance of the employees, training of the employees, manufacturing cost, along with incoming material control, production control, and storage-distribution control. Those 7 managerial factors are possible to give effects on appearance, flavor, texture, and shelf-life of milk and juices directly or indirectly.

3. *What are the CQPs of packaged beverages with bio-based materials?*

   Referring to 'irreversible' and 'unacceptable for consumers' related criteria, there are 19 CQPs identified through literature and expert interview methods consisting of 12 and 7 CQPs from the technological and managerial point of view, respectively. CQPs from the technological side are light, packaging material, storage-distribution temperature and time, filling temperature, pasteurization temperature and time, sealing temperature and time, oxygen, microbial load, and product properties. In addition, respecting the answer of specific research question number 2, light, oxygen, and pasteurization temperature and time are considered as conditional CQPs (tend to be CQPs but with specific conditions).

Meanwhile, CQPs from the managerial side are procedures, hygiene, compliance of the employees, training of the employees, manufacturing cost, along with incoming material control, production control, and storage-distribution control.

Another valuable insight obtained from this study is there is no change in routine quality control activities of milk and juices when the conventional PE packaging is changed to bio-based PE packaging since both packagings are similar in terms of characteristics and performances. It is also found that product quality and shelf-life remain the same.

4.2 Limitations

1. There was a limitation regarding the literature used for this research. When searching about CQP of beverages, the method of literature review only had findings from conventional packaging. No publication was found related to beverages packaged with bio-based packaging. Furthermore, in step 3B (possible quality deviations), only quality deviations in milk and juices were found. The same issue also happened when trying to find information concerning the functional properties of bio-based materials used for beverage packaging. There were findings but it seemed to be very limited. On the one hand, this is understandable because bio-based material as a more sustainable packaging is still a new area of research, there is still a lot of ongoing developments.
2. The outcomes of the research are only applicable for milk and juices that are packaged with packaging consisting of bio-based PE respecting 7 of 7 companies, where the experts work, used this material. Since conventional PE and bio-based PE have identical properties, both packagings have the same factors that influence product quality and CQPs, but this may not necessarily be generalized to other alternative packaging materials.
3. The questionnaire for experts entirely consisted of open questions, which were not a kind of confirmation questions. It was used because, in the beginning, the findings obtained were only from conventional packaging. Even though it was useful to gain new insights without interfering/ directing the experts so they might express the essential things that were not initially thought, the results of expert interviews were assumed as incomplete because the relevancy of findings obtained from the literature method could not be checked.
4. It was quite challenging to find the most relevant experts since this study involved two main aspects: sustainable packaging and quality control. When approaching experts, it was frequently observed that in the beginning, the proposed experts refused or were reluctant to participate because they thought they did not have enough knowledge for this field. For instance, sustainable packaging development managers were less capable of answering questions related to quality control activities. In contrast, the quality people only could give a superficial answer about the implementation of bio-based packaging. Some companies also

referred to the data collection to the marketing and sales department since they were assumed to be fully responsible for this breakthrough.

5. Time constraint was another limitation related to expert interviews. The first and second part of the interview were designed to guide the conversation so the experts would be able to follow and answer the questions better instead of directly asking about quality topics and to know the whole story regarding bio-packaging implementation. 2 experts spent quite long time to tell the journey of changing to more sustainable materials (which was also interesting). As a consequence, the last part of the interview was less detailed commented (compared to the other two parts). It was also related to their limited time given for this data collection.
6. Even though this research reached a minimum number of respondents, not all results were obtained via direct interviews (Skype or phone call). The written interview/ fill-in questionnaire was used to accommodate experts who had minimal time. Currently, the milk and juice companies that are using bio-based packaging for regular production are relatively big, so that the employees are quite hectic dealing with daily tasks. The answers obtained from the filled-in questionnaire were interpreted and asked for clarification 2-4 times if there was something unclear, but the subjectivity in interpreting might take place. Moreover, it also limited the chance to gain more additional insights and more detailed responses, which were typically found via normal conversation.

4.3 Recommendations

1. Due to limited findings concerning managerial factors that influence milk and juice quality, it is recommended to use other literature sources that are more relevant to management studies.
2. For further research, type of confirmation questions such as 'to what extent does this factor influence milk/ juice quality attributes?' may be useful. It helps to find the connection and relevancy between the findings of both methods. The chance of getting complete results are possible to be increased if those questions are formulated instead of 'what are the factors that influence milk/ juice quality?', the responses will be extensive and uncontrolled.
3. So far, the findings are limited to bio-based PE. Considering sustainable materials are prospective, further study on other bio-based materials for beverage packaging such as PLA and bio-PET could be undertaken, and the results between those 3 different materials could be then compared to see their patterns in preserving the quality of the products.
4. Besides CQPs, this research also discovered conditional CQPs such as light, oxygen, and pasteurization parameters. Further studies on the influence of those factors should be conducted to identify better whether they are indeed the relevant CQPs or not. For the impact of light, further study should consider companies that apply packaging with a low light barrier such as transparent plastic bottle/ less opaque milk container for their liquid foods. For the effect of pasteurization temperature-time, the data should be collected in companies which have in-pack pasteurization in their process. However, this further research is likely to take a long time until the bio-based materials are improved in terms of functional properties and used massively.

5. To study about alternative/ sustainable packaging for beverages, the recycled plastics can be considered as the topic. As stated by KIDV (Kennisinstituut Duurzaam Verpakken/ Netherlands Institute for Sustainable Packaging), more companies are now using this material because it is easier to obtain, affordable, and has almost the same environmental value as bio-based materials. Research concerning QCPs of milk and juices packaged with recycled plastics is more likely to have more respondents.

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Appendix A – The search strategies and results

What to search?	Source	Search strategies	Hits	Analysed	Relevant
Part A: CQPs of beverages in conventional packaging					
Process activities (step 2)	Web of Science	TITLE: (beverage*) *AND* TITLE: (process* or packag*)	324	46	8
Process activities (step 2)	Scopus	(TITLE (beverage*) AND TITLE (process* or packag*))	490	63	10 (6 similar)
		Total relevant publications			**12**
Quality attributes and possible quality deviations (step 3A & 3B)	Web of Science	TOPIC: (beverage*) *AND* TITLE: (quality) *AND* TOPIC: (attribute*)	108	24	9
Quality attributes and possible quality deviations (step 3A & 3B)	Web of Science	TOPIC: ((drink* OR beverage*) AND quality AND (attribute* OR propert* OR sensory OR shelf?life) AND (defect* OR deviation* OR deteriorat*)) *NOT* TOPIC: (water)	53	8	4 (2 similar)
Quality attributes and possible quality deviations (step 3A & 3B)	Web of Science	TITLE: (beverage* or drink* or tea or coffee or milk or juice* or "soft?drink" or carbon* or soda or syrup* or squash or smoothie*) *AND* TITLE: (quality) *AND* TITLE: (attribute* or propert* or character*) *AND* ALL FIELDS: (deteriorat* or defect* or deviation* or change*) *NOT* TITLE: (water)	129	21	10 (1 similar)
Quality attributes and possible quality deviations (step 3A & 3B)	Scopus	(TITLE-ABS-KEY (beverage*) AND TITLE (quality) AND TITLE-ABS-KEY (attribute*))	144	26	13 (5 similar)
Quality attributes and possible quality deviations (step 3A & 3B)	Scopus	(TITLE-ABS-KEY ((drink* OR beverage*) AND quality AND (attribute* OR propert* OR sensory OR shelf?life) AND (defect* OR deviation* OR deteriorat*)) AND NOT TITLE-ABS-KEY (water))	84	12	6 (4 similar)
Quality attributes and possible quality deviations (step 3A & 3B)	Scopus	((TITLE (beverage* OR drink* OR tea OR coffee OR milk OR juice* OR "soft?drink" OR carbon* OR soda OR syrup* OR squash OR smoothie*) AND TITLE (quality) AND TITLE (attribute* OR propert* OR character*) AND ALL (deteriorat* OR defect* OR deviation* OR change*) AND NOT TITLE (water))	320	54	20 (13 similar)
		Total relevant publications			**37**
Techno-logical/ managerial factors influencing quality attributes and CQPs (step 4 and 5)	Web of Science	TITLE: (influence or effect or factor or affect) *AND* TOPIC: (packag* or conventional or plastic*) *AND* TOPIC: (quality) *AND* TITLE: (milk or juice*)	239	42	18
Techno-logical/ managerial factors influencing quality attributes and CQPs (step 4 and 5)	Web of Science	TITLE: (influence or effect or factor or affect) *AND* TOPIC: (fill* or bottl* or packag* or cap* or lid* or carton* or stor* or distribut* or process*) *AND* TOPIC: (sensory or shelf?life or aroma or odo?r or taste or flavo?r or colo?r or texture or appearance or attribute*) *AND* TOPIC: (quality) *AND* TOPIC: (change or deviation or defect or deteriorat*) TITLE: (milk or juice*) *NOT* TITLE: (water)	226	47	20 (13 similar)
Techno-logical/ managerial factors influencing quality attributes and CQPs (step 4 and 5)	Scopus	(TITLE (influence OR effect OR factor OR affect) AND TITLE-ABS-KEY (packag* OR conventional OR plastic*) AND TITLE-ABS-KEY (quality) AND TITLE (milk OR juice*)	224	42	13 (12 similar)
Techno-logical/ managerial factors influencing quality attributes and CQPs (step 4 and 5)	Scopus	(TITLE (influence OR effect OR factor OR affect) AND TITLE-ABS-KEY (fill* OR bottl* OR packag* OR cap* OR lid* OR carton* OR stor* OR stor* OR distribut* OR process*) AND TITLE-ABS-KEY (sensory OR shelf?life OR aroma OR odo?r OR taste OR flavo?r OR colo?r OR texture OR appearance OR attribute*) AND TITLE-ABS-KEY (quality) AND TITLE-ABS-KEY (change OR deviation OR defect OR deteriorat*) AND TITLE (milk OR juice*)) AND NOT TITLE (water))	197	38	16 (13 similar)
Managerial factors influencing quality attributes and CQPs	Web of Science	TOPIC: (manage* or activit* or control) *AND* TITLE: (milk or juice*) *AND* TOPIC: (quality) *AND* TOPIC: (industr* or compan* or manufactur*) *AND* TITLE: (human or people or worker* or operator* or employee* or handl*)	17	5	1 (1 similar)
Managerial factors influencing quality attributes and CQPs	Web of Science	TOPIC: (manage* or activit* or control) *AND* TITLE: (beverage* or drink*) *AND* TOPIC: (quality) *AND* TOPIC: (industr* or compan* or manufactur*) *AND* TITLE: (human or people or worker* or operator* or employee* or handl*)	7	1	0

What to search?	Source	Search strategies	Hits	Analysed	Relevant
(step 4 and 5)		TOPIC: ("good manufacturing practice*") *AND* TOPIC: (process* or pack* or stor* or distribut* or transport* or handl*) *AND* TOPIC: (quality) *AND* TITLE: (milk or juice*)	21	0	0
		TOPIC: (good manufacturing practice*) *AND* TOPIC: (process* or pack* or stor* or distribut* or transport* or handl*) *AND* TOPIC: (quality) *AND* TITLE: (beverage* or drink*)	5	2	0
	Scopus	(TITLE-ABS-KEY (manage* OR activit* OR control) AND TITLE (milk OR juice*) AND TITLE-ABS-KEY (quality) AND TITLE-ABS-KEY (industr* OR compan* OR manufactur*) AND TITLE (human OR people OR worker* OR operator* OR employee* OR handl*))	22	3	1 (1 similar)
		(TITLE-ABS-KEY (manage* OR activit* OR control) AND TITLE (beverage* OR drink*) AND TITLE-ABS-KEY (quality) AND TITLE-ABS-KEY (industr* OR compan* OR manufactur*) AND TITLE (human OR people OR worker* OR operator* OR employee* OR handl*))	8	0	0
		(TITLE-ABS-KEY ("good manufacturing practice*") AND TITLE-ABS-KEY (process* OR pack* OR stor* OR distribut* OR transport* OR handl*) AND TITLE-ABS-KEY (quality) AND TITLE (milk OR juice*))	21	1	0
		(TITLE-ABS-KEY ("good manufacturing practice*") AND TITLE-ABS-KEY (process* OR pack* OR stor* OR distribut* OR transport* OR handl*) AND TITLE-ABS-KEY (quality) AND TITLE (beverage* OR drink*))	6	1	0
	Science Direct	Title, abstract, keywords: quality AND (beverage OR beverages) AND (industry OR industries OR company OR companies) AND (management OR control) AND (human OR people)	160	16	2
		Title, abstract, keywords: good manufacturing practice AND (milk OR juice OR juices)	176	14	5 (1 similar)
	Total relevant publications				**35**
Part B: Functional properties of bio-based materials for beverage packaging					
Bio-based materials for beverage packaging	Web of Science	TITLE: (sustainable or alternative or bio?based or bio?polymer* or plant?based or bio or plastic* or material*) *AND* TITLE: (milk or juice*) *AND* TOPIC: (packag*) *NOT* TOPIC: (active or intelligent or smart or edible)	54	12	1
		TITLE: (sustainable or alternative or bio?based or bio?polymer* or plant?based or bio or plastic* or packag*) *AND* TITLE: (beverage* or drink*) *AND* TOPIC: (technolog* or material* or character* or propert*) *NOT* TOPIC: (active or intelligent or smart or edible)	180	0	0
		TITLE: (packag* AND material*) *AND* TITLE: (plastic* or bio) *AND* TOPIC: (food or beverage*) *NOT* TOPIC: (active or intelligent or smart or edible or antimicrob* or water)	39	3	0
	Scopus	(TITLE (sustainable OR alternative OR bio?based OR bio?polymer* OR plant?based OR bio OR plastic* OR material*) AND TITLE (milk OR juice*) AND TITLE-ABS-KEY (packag*) AND NOT TITLE-ABS-KEY (active OR intelligent OR smart OR edible))	72	21	1 (1 similar)
		(TITLE (sustainable OR alternative OR bio?based OR bio?polymer* OR plant?based OR bio OR plastic* OR packag*) AND TITLE (beverage* OR drink*) AND TITLE-ABS-KEY (technolog* OR material* OR character* OR propert*) AND NOT TITLE-ABS-KEY (active OR intelligent OR smart OR edible))	280	23	3
		(TITLE (packag* AND material*) AND TITLE (plastic* OR bio) AND TITLE (food OR beverage*) AND NOT TITLE-ABS-KEY (active OR intelligent OR smart OR edible OR antimicrob* OR water))	43	6	2
	Total relevant publications				**6**

Appendix B – Critical appraisal table

Part A. Process activities (step 2)

Publications	Aim	Type of study	Type of beverage	Type of packaging	Process activities mentioned
Manfredi, M., & Vignali, G. (2015). Comparative Life Cycle Assessment of hot filling and aseptic packaging systems used for beverages. *Journal of Food Engineering*, *147*, 39-48.	The purpose of this study is therefore to evaluate the impacts associated with hot filling and aseptic packaging systems in order to assess the environmental sustainability of the two systems, and to try to understand if, from an environment-tal point of view, it is possible to determine which is more eco-friendly	Empirical	Orange juice	Conven-tional	From hot filling: … → heating → filling → corking phase → holding time → cooling → container drying → checker and coder → labelling → cartoning → palletizing From aseptic filling: … → heating → holding time → cooling → filling (room temperature) → corking phase → container drying → checker and coder → labelling → cartoning → palletizing

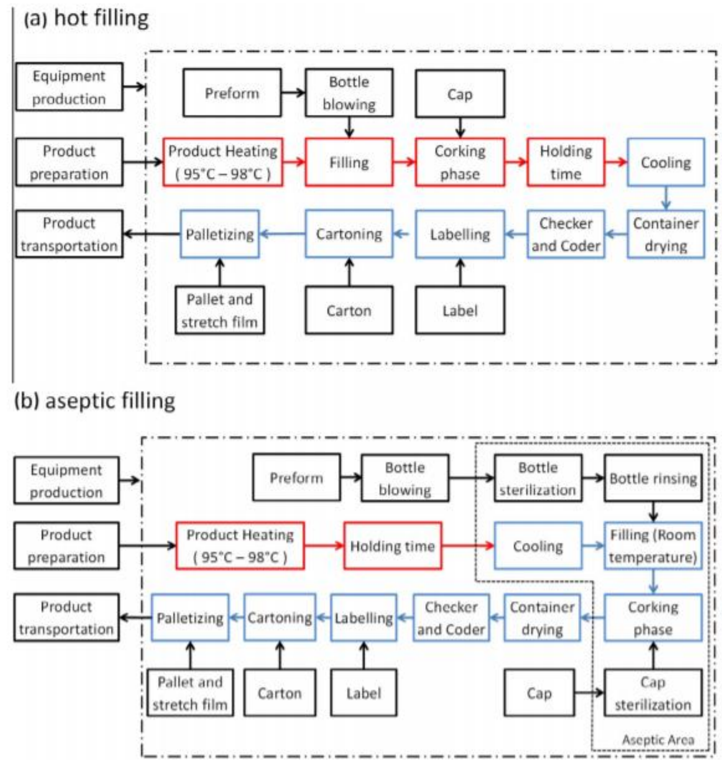


Fig. 3. Graphical scheme of the production systems assessed (the dotted line defines the system boundaries); blue cells indicate cold phases while red cells indicate hot phases. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

<table>
<tr><th>Publications</th><th>Aim</th><th>Type of study</th><th>Type of beverage</th><th>Type of packaging</th><th>Process activities mentioned</th></tr>
<tr>
<td>Monteiro, M. J. P., Costa, A. I. A., Fliedel, G., Cissé, M., Bechoff, A., Pallet, D., Tomlins, K., & Pintado, M. M. E. (2017). Chemical-sensory properties and consumer preference of hibiscus beverages produced by improved industrial processes. Food chemistry, 225, 202-212.</td>
<td>This paper evaluates the physicochemical properties of three beverages resulting from such changes, vis-à-vis those of conventionally manufactured ones, and determines their impact on the products' sensory evaluation and local consumer preference.</td>
<td>Empirical</td>
<td>Hibiscus beverages</td>
<td>Conven-tional</td>
<td>Grinding → extraction → filtration → mixing (sugar addition) → pasteurization → rapid cooling and packaging → storage

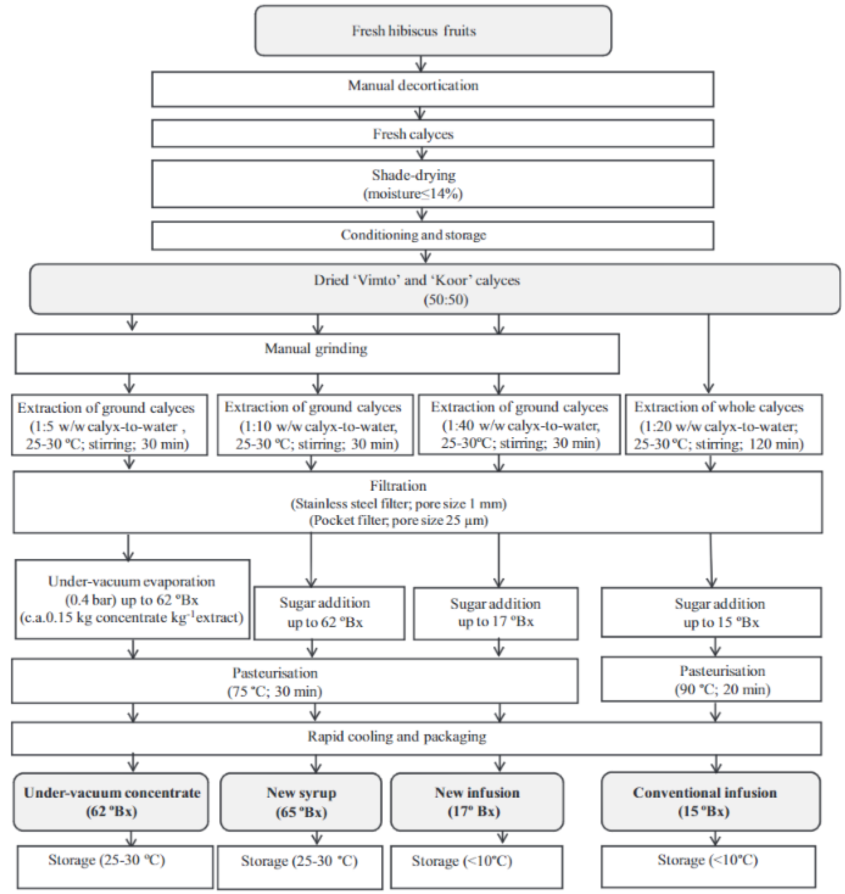
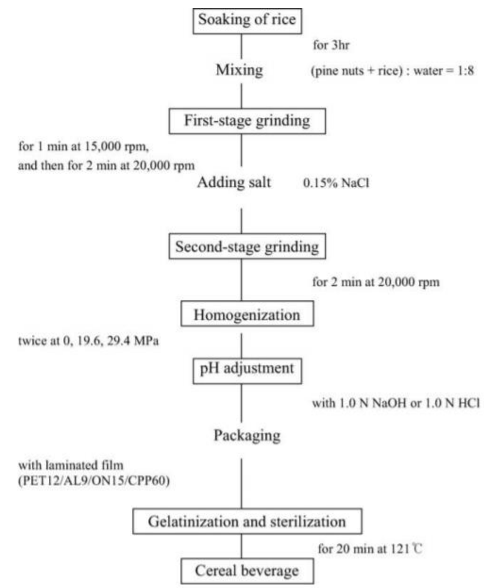
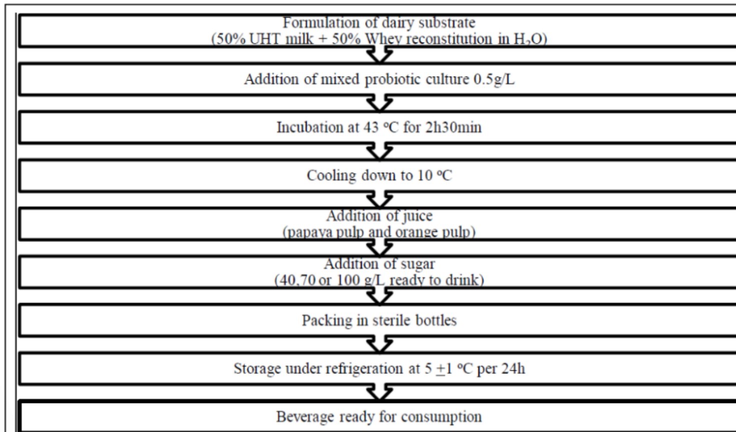
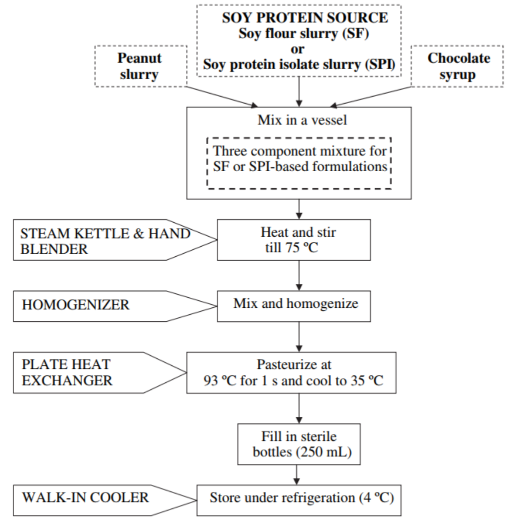
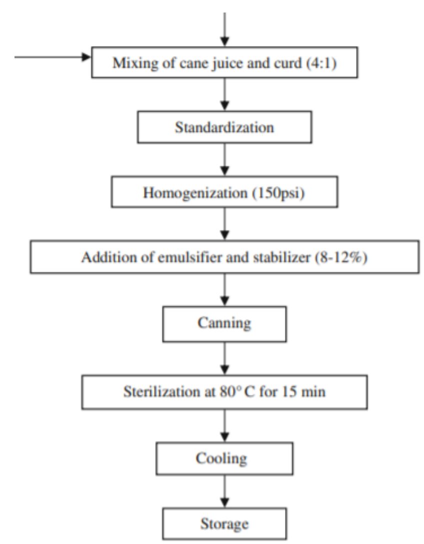
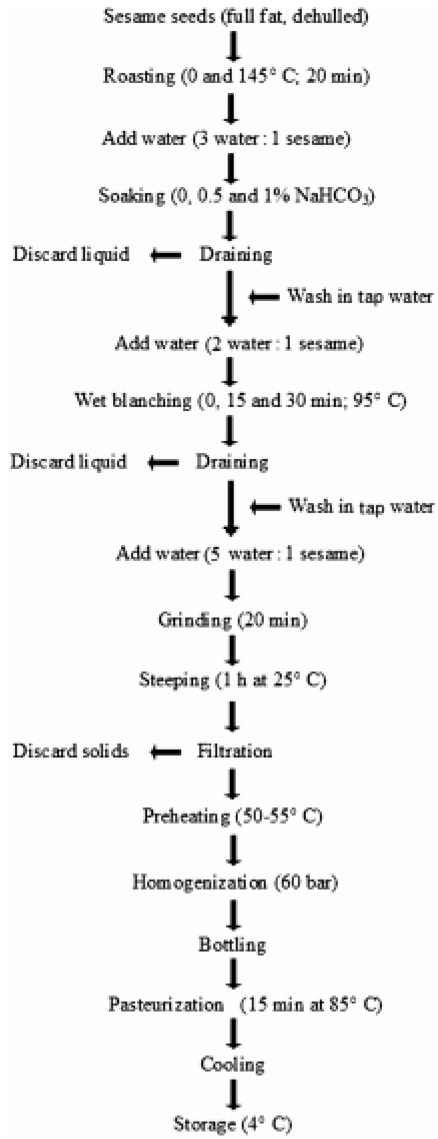


Fig. 1. Processes of production of the four hibiscus beverages.</td>
</tr>
</table>

Publications	Aim	Type of study	Type of beverage	Type of packaging	Process activities mentioned
Lee, S. W., & Rhee, C. (2003). Processing suitability of a rice and pine nut (Pinus koraiensis) beverage. *Food hydrocolloids*, *17*(3), 379-385.	The overall objective of this work was to investigate the processing suitability of a cereal beverage with pine nuts.	Empirical	Rice and pine nut beverage	Conven-tional	Mixing → packaging → sterilization  Fig. 1. Flow diagram for preparation of cereal beverage with pine nuts (*P. koraiensis*).
Andrade, M. R. D., Martins, T. R., Rosenthal, A., Hauck, J. T., & Deliza, R. (2019). Fermented milk beverage: formulation and process. *Ciência Rural*, *49*(3).	The present study aimed to develop a papaya and orange flavored fermented dairy beverage mixed with probiotic culture and to identify the most appropriate formulation from a sensorial and nutritional standpoint.	Empirical	Fermented milk beverage	Conven-tional	Mixing → packing in sterile bottles → storage  Figure 1 - Flowchart for preparation of beverages.

Publications	Aim	Type of study	Type of beverage	Type of packaging	Process activities mentioned
Deshpande, R. P., Chinnan, M. S., & Phillips, R. D. (2008). Process development of a chocolate-flavoured peanut–soy beverage. *International journal of food science & technology*, *43*(5), 886-894.	The objective was to develop a protein-rich beverage utilising three major ingredients, peanut, soy and chocolate.	Empirical	Chocolate-flavoured peanut–soy beverage	Conven-tional	Mixing → heating → homogenizing → pasteurization → filling → storage  **Figure 3** Processing steps for chocolate-flavoured peanut–soy beverage.
Singh, R. K., Jha, A., Singh, C. K., & Singh, K. (2012). Optimization of process and physico-chemical properties of ready-to-serve (RTS) beverage of cane juice with curd. *Sugar Tech*, *14*(4), 405-411.	The purpose of this investigation was to optimize the process for manufacturing cane-curd RTS beverage from different composition ratios of cane and curd and to study the effect of storage conditions on physico-chemical, microbial and sensory quality of cane curd RTS beverage.	Empirical	Cane juice with curd	Conven-tional	Mixing → canning/ bottling → sterilization → cooling → storage 

Publications	Aim	Type of study	Type of beverage	Type of packaging	Process activities mentioned
Ahmadian-Kouchaksaraei, Z., Varidi, M., Varidi, M. J., & Pourazarang, H. (2014). Influence of processing conditions on the physicochemical and sensory properties of sesame milk: A novel nutritional beverage. *LWT-Food Science and Technology*, *57*(1), 299-305.	The present study was designed: (a) to examine the effects of NaHCO3 concentration in soaking water, roasting temperature and blanching time on selected chemical, physical and sensory properties of sesame milk; and (b) to determine the optimum conditions for production of sesame milk.	Empirical	Sesame milk	Conven-tional	… → filtration → preheating → homogenization → bottling → pasteurization → cooling → storage  Fig. 1. Flow diagram for the preparation of sesame milk.

Publications	Aim	Type of study	Type of beverage	Type of packaging	Process activities mentioned
Bertolini, M., Bottani, E., Vignali, G., & Volpi, A. (2013). Analysis and life cycle comparison of different packaging systems in the aseptic beverages sector. *Proceedings of the Summer School Francesco Turco, Senigallia, Italy*, 11-13.	The aim of this study is to carry out a comparative analysis of the environmental impact of different types of packaging materials adopted in the aseptic beverages field.	Empirical	Milk	Conven-tional	... → sterilization → drying → filling → closure/ capping -If considering an ESL milk with a shelf life of at least 30 days two main aseptic packaging systems can be adopted: i) a Form Fill Seal (FFS) technology for flexible container, such as multilayer carton, ii) a Controlled Contamination (CC) technology for filling rigid (e.g. glass) and semi-rigid (e.g. PET and HDPE) packaging materials. Both systems exploit a clean room with an air positive pressure and the same phases of sterilization, drying, filling and closure. However, in the first case all these operations are performed in a single room following a vertical flow; conversely in the second case, three rotary carousels are used to move the bottles between the room of sterilization, drying, filling and capping. -The results obtained show that the multilayer carton is the most environmental friendly solution for almost all the impact categories considered and its environment impacts are on average more than 30% lower than both PET with sleever label and HDPE.

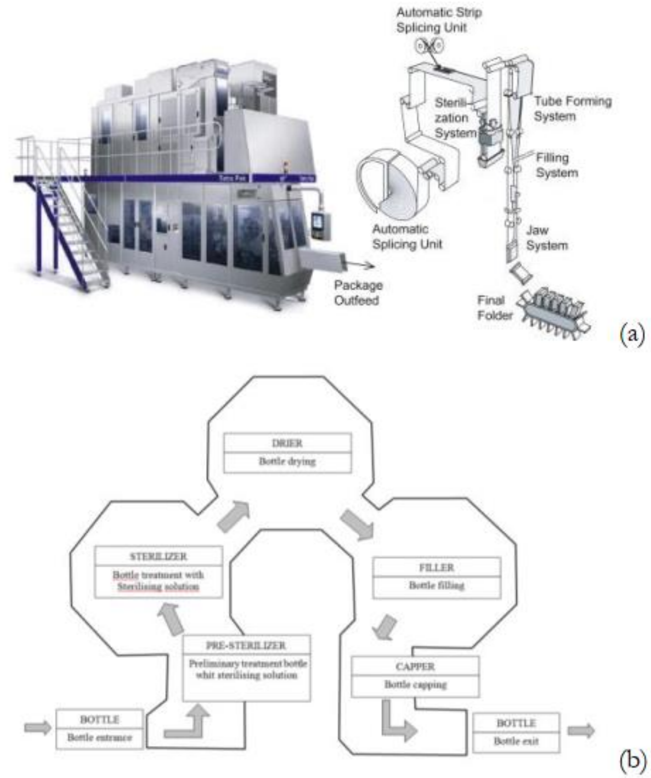
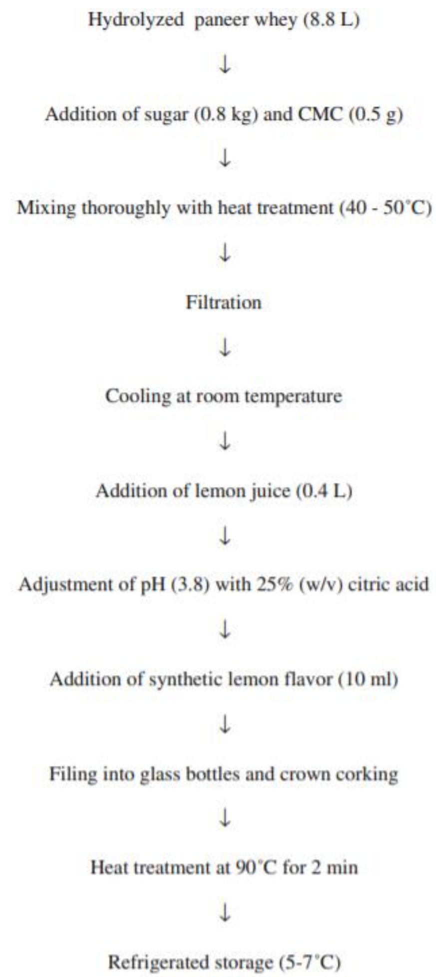
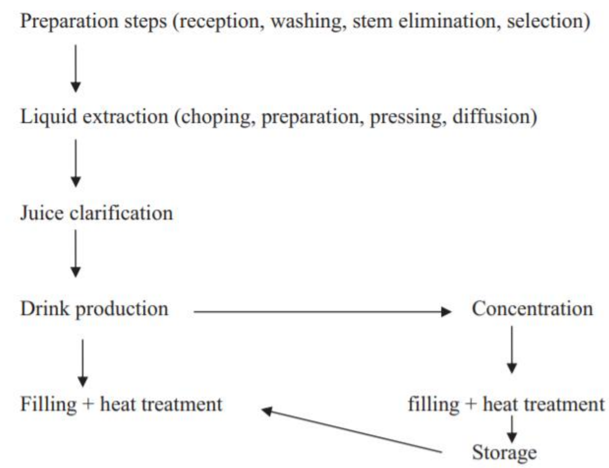
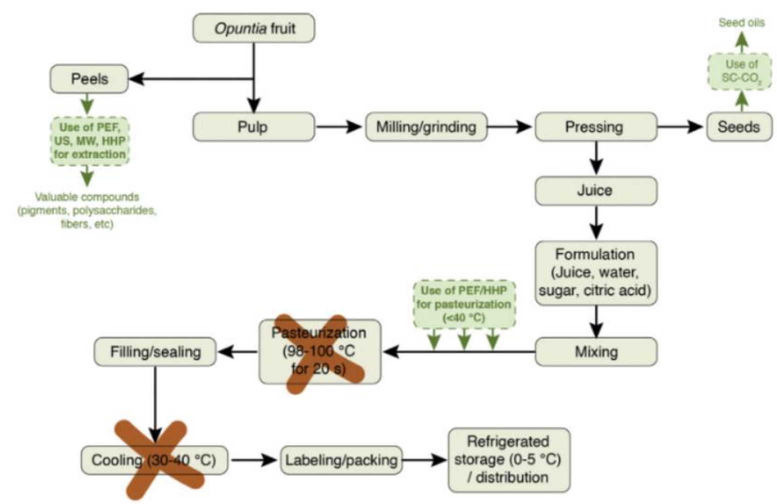
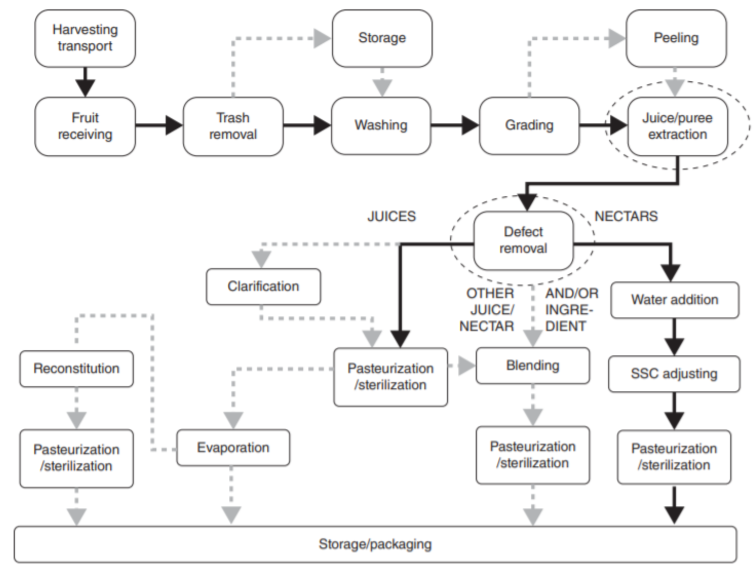


Figure 1: aseptic technology for flexible packaging (a) and rigid and semi-rigid packaging (b)

Publications	Aim	Type of study	Type of beverage	Type of packaging	Process activities mentioned
Singh, S., Khemariya, P., & Rai, A. (2014). Process optimization for the manufacture of lemon based beverage from hydrolyzed whey. *Journal of food science and technology*, *51*(4), 691-699.	The present investigation was undertaken to develop a lemon beverage utilizing lactose hydrolyzed paneer whey.	Empirical	Lemon based beverage	Conven-tional	Mixing → filling into glass bottles and crown corking → heat treatment → storage 
Pasvanka, K., Varzakas, T., & Proestos, C. (2017). Minimally Processed Fresh Green Beverage Industry (Smoothies, Shakes,		Book chapter	Fruit juice	Conven-tional	Prepared fruit drinks are filled into glass or plastic bottles of alternative shape and size, but they can also be packed into combined boxes. Fruit juices are maintained with heat treatment. According to the traditional method, the juice is heated up to 82–85 °C, then filled at that temperature, closed, and then pasteurized. Pasteurization is executed at 84–88 °C for 15–45 min depending on the size of the packaging. Coming after heat treatment, products are cooled back to room temperature. Nevertheless, the aseptic procedure preserves juice quality much better. This means that the juice is pasteurized when flowing in a closed system, and

Publications	Aim	Type of study	Type of beverage	Type of packaging	Process activities mentioned
Frappes, Pop Ups). In *Minimally Processed Refrigerated Fruits and Vegetables* (pp. 513-536). Springer, Boston, MA.					then cooled under conditions where no infection may occur, and finally filled into sterilized containers. This procedure applies heat treatment of 100–110 °C for 0.5–1.5 min. Preparation → production → fiiling + heat treatment → storage 
Barba, F. J., Putnik, P., Kovačević, D. B., Poojary, M. M., Roohinejad, S., Lorenzo, J. M., & Koubaa, M. (2017). Impact of conventional and non-conventional processing on prickly pear (Opuntia spp.) and their derived products: From preservation of beverages to valorization of by-products. *Trends in food science & technology*, *67*, 260-270.	The purpose of this publication is to review 1) the effect of various food preservation processing methods on degradation of phyto-chemical compounds from Opuntia fruits, and 2) the impact of conventional and innovative processing methods on recovering the high-added value compounds from Opuntia fruit by-products/waste.	Empirical	Pear beverage	Conven-tional	Mixing → (pasteurization) → filling/ sealing → cooling → labelling/ packing → storage (adapted from FAO) 

Publications	Aim	Type of study	Type of beverage	Type of packaging	Process activities mentioned
Reyes-De-Corcuera, J. I., Goodrich-Schneider, R. M., Barringer, S. A., & Landeros-Urbina, M. A. (2014). 15 Processing of Fruit and Vegetable Beverages. *Principles and Applications*, 339.		Book chapter	Milk, juice	Conven-tional	Milk packaging (filling): The different filling systems used in the dairy industry are form fill and seal, aseptic filling, and bottle filling. In the form fill and seal system, the packaging material is made to form a container in the filling machine; the product is filled into this container and then sealed. This method is used for plastic pouches and paper cartons. Aseptic filling is utilized for aseptically packaged milk products where a sterile product is filled into a sterile container under aseptic conditions. For juice: Blending/ mixing → (clarification) → pasteurization/ sterilization → storage/ packaging 
Total relevant publications: 12					

Quality attributes (step 3A)

Publications	Aim	Type of study	Type of beverage	Quality attributes mentioned	Detail
Aishah, B., Hannah, K., & Alyani, O. Z. (2016). Stability of selected quality attributes of pink guava juice during storage at elevated temperatures. *International Food Research Journal*, *23*(5), 1918.	The purpose of this study was to determine the degradation rate of vitamin C, lycopene, total phenolic and antioxidant activity during storage of pink guava juice.	Empirical	Pink guava juice	Colour	-In pink flesh guava fruit, its attractive colour is attributed to the presence of the carotenoids pigment, lycopene. The colour intensity of the fruit is directly proportional to the lycopene content in the fruit flesh as well as the colour and lycopene amount in the juice made from the fruit.
Andueza, S., Vila, M. A., Paz de Peña, M., & Cid, C. (2007). Influence of coffee/water ratio on the final quality of espresso coffee. *Journal of the Science of Food and Agriculture*, *87*(4), 586-592.	The aim of this work was to evaluate the influence of coffee/ water ratio on the physico-chemical and sensory quality of espresso coffee.	Empirical	Espresso coffee	Aroma, colour, taste, bitterness, astringency, viscosity	-Sensorial properties which include a full fine aroma (intense), dark brown colour, a bitter/acid balance taste (strong) and a pleasant lingering aftertaste, exempt from unpleasant flavour defects. -This type of roast contributes to the brownish colour of the coffee. -A higher viscosity was observed in Arabica espresso coffee, which also had higher amounts of lipids. -The formation of other unidentified bitter compounds derived from Maillard reactions and caramelisation during roasting contribute to the greater bitterness and astringency of Robusta blends espresso coffee.
Bertrand, B., Boulanger, R., Dussert, S., Ribeyre, F., Berthiot, L., Descroix, F., & Joët, T. (2012). Climatic factors directly impact the volatile organic compound fingerprint in green Arabica coffee bean as well as coffee beverage quality. *Food chemistry*, *135*(4), 2575-2583.	This study was aimed at determining whether climatic conditions during bean development affected sensory perception of the coffee beverage and combinations of volatile compounds in green coffee	Empirical	Green Arabica coffee	Aroma, acidity, fruitiness, taste	-Combinations of volatile organic compounds determine the aroma of fruits and vegetables. -The volatile composition of roasted coffee is likely one of the most important factors for determining coffee character and quality. -Aroma quality, acidity, fruitiness and overall quality were favoured by cool climates, whilst the undesirable earthy and green tastes were increasingly present as the temperature increased.
Bulatović, M. L., Krunić, T. Ž., Vukašinović-Sekulić, M. S., Zarić, D. B., & Rakin, M. B. (2014). Quality attributes of a fermented whey-based beverage enriched with milk and a probiotic strain. *RSC Advances*, *4*(98), 55503-55510.	The main objectives of this paper were to study the influence of milk and additional probiotic strain Lactobacillus rhamnosus ATCC 7469 on the quality attributes of a fermented whey-based beverage containing commercial ABY-6 starter culture.	Empirical	Whey-milk beverage	Mouthfeel, viscosity	-Consumers perceive whey-based beverages as watery, sweet–sour liquid with the poor mouthfeel. Likewise, beverages produced by fermentation of whey have significantly lower viscosity, milder flavour compared to those obtained by fermentation of milk. -The presence of exopolysaccharides leads to the improvement of textural attributes (such as firmness and mouthfeel) of many food products. Many of them can form gels that will constitute food structure and enhance viscosity of solutions. -Casein content had high influence on the texture of fermented milk products. -Milk helps to avoid the poor sensory characteristics perceptible to consumers and in synergy with exopolysaccharides greatly improves the viscosity and syneresis of beverage.

Publications	Aim	Type of study	Type of beverage	Quality attributes mentioned	Detail
Della Lucia, F., Do Carmo, J. R., Morais, C. S. N., Nunes, C. A., Pinheiro, A. C. M., Ferreira, E. B., ... & Vilas Boas, E. V. D. B. (2016). Physicochemical and sensory quality of several commercial Brazilian chocolate milk beverages. *International Journal of Dairy Technology*, *69*(3), 364-371.	This study aimed at determining the physicochemical and sensory quality of commercial chocolate milk beverages and the contribution of the CATA methodology and internal preference mapping (regular and PARAFAC approaches) to the acceptability evaluation.	Empirical	Chocolate milk	Aroma, flavour (taste), colour, brightness, sandiness	-Chocolate milk was characterised by milk aroma, a weak to strong chocolate aroma, weak to strong chocolate/ milk flavour, brown colour, brightness and sandiness. -The attributes of strong chocolate aroma, strong chocolate flavour, strong brown colour, brightness and sandiness can be associated with dislike. However, another study said cocoa aroma is a major driver of consumers' liking.
Hemalatha, R., Kumar, A., Prakash, O., Supriya, A., Chauhan, A. S., & Kudachikar, V. B. (2018). Development and Quality Evaluation of Ready to Serve (RTS) Beverage from Cape Gooseberry (Physalis peruviana L.). *Beverages*, *4*(2), 42.	This study aimed to develop a process for the development of ready to serve (RTS) beverages from enzyme liquefied (pectinase) Cape gooseberry juice with additives and preservatives.	Empirical	Cape gooseberry juice	Viscosity	-The increase in viscosity of the RTS beverage samples could be explained by the interactions of the pectin molecule, citric acid, sugar, and liquid phase of the RTS beverage of Cape gooseberry. -Phenolic compounds play some vital role in the quality of processed food products like flavor and taste.
Ribeiro, J. S., Augusto, F., Salva, T. J. G., & Ferreira, M. M. C. (2012). Prediction models for Arabica coffee beverage quality based on aroma analyses and chemometrics. *Talanta*, *101*, 253-260.	... to improve the correlation between chromatographic data and sensory analysis, to introduce more attributes, such as acidity and bitterness, and to identify the significant volatile compounds related to each PLS model.	Empirical	Arabica coffee	Aroma, acidity, cleanliness, bitterness, flavour	-Aroma is one of the most important attributes of the coffee beverage. Thus, it has recently been highly valued and widely used to discriminate high-quality coffees acidity, cleanliness, overall quality, bitterness, body, and flavor of the beverage.
Skoczylas, Ł., Korus, A., Tabaszewska, M., Gędoś, K., & Szczepańska, E. (2018). Evaluation of the quality of fresh and frozen wheatgrass juices depending on the time of grass harvest. *Journal of Food Processing and Preservation*, *42*(1), e13401.	The aim of the study was to assess WgJ quality immediately after squeezing and after a 3-month period of frozen storage.	Empirical	Wheatgrass juice	Colour, appearance	...stressed that for consumers, juice color is a crucial indicator of the quality, attractiveness, and acceptability of a product; consumers wish to buy products with intense color and natural appearance.
Bolarinwa, I. F., Aruna, T. E., Adejuyitan, J. A., Akintayo, O. A., & Lawal, O. K. (2018). Development and quality evaluation of soy-walnut milk drinks. *International Food Research Journal*, *25*(5).	The objectives of this study are therefore to determine the proximate and mineral content, physicochemical properties, and consumer acceptability of the milk drinks.	Empirical	Soy-walnut milk	Colour	-The higher the percentage composition of malted soymilk substitution (>10%), the more the colour of the milk drinks changes from white to cream colour.

Publications	Aim	Type of study	Type of beverage	Quality attributes mentioned	Detail
Evrendilek, G. A., Celik, P., Agcam, E., & Akyildiz, A. (2017). Assessing impacts of pulsed electric fields on quality attributes and furfural and hydroxymethylfurfural formations in apple juice. *Journal of food process engineering*, *40*(5), e12524.	...to quantify and compare effects of changing the processing variables of electric field strength, treatment time, temperature, and energy on physical properties, bioactive compounds, and formations of furfural and HMF for PEF processed apple juice.	Empirical	Apple juice	Acidity, flavour, astringency, stability (shelf-life)	-Stability of pH is important because low pH value is well known to prevent pathogenic microbial growth in fruit juices, an important feature that affects its overall quality. -Acidity in apple juice is an important quality attribute associated with its characteristic flavor and astringency.
İçier, F., Gündüz, G. T., Yılmaz, B., & Memeli, Z. (2015). Changes on some quality characteristics of fermented soy milk beverage with added apple juice. *LWT-Food Science and Technology*, *63*(1), 57-64.	The aim of this study was to combine soymilk and apple juice at different concentrations to produce a new fermented soymilk drink, and also to determine the survival of L. acidophilus and changes on rheological properties throughout the storage period of 21 days.	Empirical	Soy milk + apple juice	Flavour, viscosity	-Specific flavor of soymilk can be masked by the addition of sugar, aromas and fruit paste. -The apparent viscosity of the fruit purees (raspberry, strawberry, peach and prune) was affected by the increasing with sugar content.
Rodrigo, D., Arranz, J. I., Koch, S., Frígola, A., Rodrigo, M. C., Esteve, M. J., ... & Rodrigo, M. (2003). Physicochemical characteristics and quality of refrigerated Spanish orange-carrot juices and influence of storage conditions. *Journal of food science*, *68*(6), 2111-2116.	...to study the physicochemical characteristics and quality of various Spanish refrigerated orange and carrot juice mixtures and their stability over time (1 to 6 week).	Empirical	Orange-carrot juice	Turbidity	-The results of turbidity are related with the ones of percentage of pulp because a great part of the turbidity is due to it. -The variation between the juices may, once again, be due to differences in raw material.
Tastan, O., & Baysal, T. (2015). Clarification of pomegranate juice with chitosan: changes on quality characteristics during storage. *Food chemistry*, *180*, 211-218.	...to determine the effects of the process temperature, and process time on the turbidity and a⁄ values of juice, and to compare the quality characteristics of PJ during storage at 4 and 20 C for 6 months.	Empirical	Pomegranate juice	Colour, appearance, astringency, bitterness, turbidity	-Anthocyanins are responsible for the bright red colour of pomegranate juice (PJ) and this red colour is one of the major quality parameters of PJ that affects consumer sensory acceptance. Additionally, anthocyanins are also responsible for the appearance, astringency, and bitterness. -The turbidity of a fruit juice is caused mainly by the presence of pectins and polyphenols. -PJs also became turbid during storage as the storage temperature and time increased.
Martin, N., Carey, N., Murphy, S., Kent, D., Bang, J., Stubbs, T., ... & Dando, R. (2016). Exposure of fluid milk to LED light negatively affects consumer perception and alters underlying sensory	This study is the first to demonstrate the effects of LED lighting on consumer perception of fluid milk.	Empirical	Fluid milk	Flavour, odor	-Microbial contamination and growth are major contributors to fluid milk quality. A major group of microorganisms responsible for fluid milk spoilage is represented by gram-negative bacteria, such as *Pseudomonas* sp., which are introduced into the product postprocessing. These organisms typically are responsible for sensory defects described as fruity, barny, and shrimpy.

Publications	Aim	Type of study	Type of beverage	Quality attributes mentioned	Detail
properties. *Journal of dairy science*, *99*(6), 4309-4324.					once introduced into the fluid milk supply, leading to major sensory defects in flavor, odor, and body.
Tomadoni, B., Cassani, L., Viacava, G., Moreira, M. D. R., & Ponce, A. (2017). Effect of ultrasound and storage time on quality attributes of strawberry juice. *Journal of Food Process Engineering*, *40*(5), e12533.	...to determine the effect of ultrasound treatment in comparison with thermal treatment on the physicochemical properties (color, total soluble solids, and total acidity), microbial growth, total phenolic content, and antioxidant activity (DPPH) of strawberry juice during shelf life.	Empirical	Strawberry juice	Colour, aroma, sweetness-sourness, mouthfeel	-Color is an important attribute of juice quality because it can condition its acceptability by the consumer. -Among fruit juices, strawberry juice is one of the most popular, due to its attractive color, good aroma and sweet–sour mouthfeel.
Wiking, L., Frøst, M. B., Larsen, L. B., & Nielsen, J. H. (2002). Effects of storage conditions on lipolysis, proteolysis and sensory attributes in high quality raw milk. *Milchwissenschaft*, *57*(4), 190-194.	...to study whether storage of high quality raw milk at 4 and 8ºC affect proteolysis, lipolysis, and sensory attributes during 72h.	Empirical	Raw milk	Aroma, flavour, creaminess	-A significant effect of the storage duration in the following 5 descriptors: cream aroma, cream flavour, boiled milk flavour, metallic flavour, and creaminess.
Chen, L., Bi, X., Guo, D., Xing, Y., & Che, Z. (2019). The effect of high-power ultrasound on the quality of carrot juice. *Food Science and Technology International*, 1082013219825736.	...to investigate in detail the effect of HPU treatment on the quality of carrot juice including enzymes' activity (PPO, POD and PME), physicochemical attributes (TSS, pH, viscosity, turbidity, particle size distribution and colour) and carotenoids' content.	Empirical	Carrot juice	Turbidity, colour	-The increase of turbidity might be caused by the breakdown of macro-molecules like pectin. -Carotenoids contributed to the colour of carrot juice.
Karadağ, A., Avci, N., Kasapoğlu, K. N., & Özçelik, B. (2016). Effect of microwave technology on some quality parameters and sensory attributes of black tea. *Czech Journal of Food Sciences*, *34*(5), 397-405.	The present study was aimed to use microwave technology in withering and drying steps of black tea processing.	Empirical	Black tea	Taste, astringency, colour, mouthfeel, thickness	-The oxidation of catechins occurs through enzymecatalysed reactions to form theaflavins (TF) and thearubigins (TR); theaflavins are bright and orangered while thearubigins are more chemically heterogeneous and tend to be brownish red. Theaflavins have astringent tastes and contribute to briskness, astringency, and colour of black tea while thearubigins are responsible for the mouth feel (thickness) and colour of tea.
Kreuml, M. T., Majchrzak, D., Ploederl, B., & Koenig, J. (2013). Changes in sensory quality characteristics of coffee during storage. *Food Science & Nutrition*, *1*(4), 267-272.	there is the need to investigate how long roasted coffee beans can be stored without reducing the typical flavor of coffee beverages, which is mainly	Empirical	Coffee	Odour, flavour, taste, astringency, bitterness, staleness (shelf-life)	-The coffee brews prepared from freshly roasted Arabica and Robusta beans has overall coffee odor and flavor, brew-like, roasty, and fruity/aromatic as well as the sweet taste. -In contrast, the negative associated odor and flavor attributes like burnt/smoky, woody, earthy, and hay like as well as the astringency, bitter taste, and aftertaste increased significantly

Publications	Aim	Type of study	Type of beverage	Quality attributes mentioned	Detail
	responsible for the consumers' enjoyment.				during storage. In addition, staleness and rancid odor and flavor, were particularly perceivable after 18 months of storage.
Laaksonen, O., Mäkilä, L., Tahvonen, R., Kallio, H., & Yang, B. (2013). Sensory quality and compositional characteristics of blackcurrant juices produced by different processes. *Food chemistry*, *138*(4), 2421-2429.	The aim of this study was to compare the enzyme-aided blackcurrant processing with non-enzymatic juice pressing.	Empirical	Blackcurrant juice	Sourness, bitterness, astringency, flavour, sweetness	-Commercial juices are commonly diluted with water and/or sweetened with sugar or other sweeteners to reduce or mask the sourness, bitterness and astringencies, resulting in increased sugar content and altered flavour of the juices. -Products with high content of blackcurrant juice may be perceived as bitter and astringent. -Juices of different blackcurrant cultivars varied in sweetness, sourness and bitterness. The most intensive sensory attributes of the juices were sourness and puckering astringency.
Laukalēja, I., & Krūma, Z. (2018). Quality of specialty coffee: balance between aroma, flavour and biologically active compound composition. *Research for Rural Development*, *1*.	The aim of this review was to summarize recent scientific developments about composition of aroma, flavour and biologically active compounds in specialty coffee and evaluate the best possibilities to balance health promoting and flavour attributes	Review	Coffee	Texture, aroma, taste, flavour, sweetness, astringency	Specialty coffee quality is focused on the texture, aroma and taste of the drink, but focusing mainly on the flavour compounds, the balance of biologically developments about composition of aroma, flavour and biologically active compounds in specialty coffee and evaluate the best possibilities to balance health promoting and flavour attributes The sweetness and acidity is highly influenced by organic acid balance – malic, citric and phosphoric acid. Malic and citric acids have positive correlation with sucrose content in coffee
Lopez-Nicolas, J. M., Andreu-Sevilla, A. J., Carbonell-Barrachina, A. A., & García-Carmona, F. (2009). Effects of addition of α-cyclodextrin on the sensory quality, volatile compounds, and color parameters of fresh pear juice. *Journal of agricultural and food chemistry*, *57*(20), 9668-9675.	... to study the intensities of odor, aroma, and global quality of the pear juice in the presence of different concentrations of R-CD by a trained sensory panel.	Empirical	Fresh pear juice	Colour, aroma, odor	-Pear juice has yellow and green color. -Esters are the most significant contributors to the aroma of pears. -In the fresh juice, the main compounds were butyl acetate (main sensory descriptors: apple-like, fresh, fruity), R-farnesene (mild sweet, green herbaceous), hexyl acetate (sweet fruity), hexanal (green, grass-like, fruity), and 1-butanol (cheesy, light-fruity). -The darker the color of the juice (higher intensity of color), the more intense the sensory odor.
Ratnasooriya, C. C., Rupasinghe, H. P., & Jamieson, A. R. (2010). Juice quality and polyphenol concentration of fresh fruits and pomace of selected Nova Scotia-grown grape cultivars. *Canadian journal of plant science*, *90*(2), 193-205.	The objective of this study was to identify suitable cultivars for the development of ''red-wine-like'' functional beverages from grapes grown in Nova Scotia.	Empirical	Grape juice	Sweetness, acidity, flavour, colour	-The sensory attributes of grape juice are largely dependent on the balance among the sugars, acids, natural flavours, phenolic compounds and colour components. -The juice of the wine grapes was dark purple, while the table grapes ranged from brownish orange to light yellow.
Zhu, M. Z., Wen, B., Wu, H., Li, J., Lin, H., Li, Q., ... & Liu, Z. (2019). The Quality Control of Tea by Near-Infrared	In this article, we review the most recent advances and applications of NIR spectroscopy and chemometrics	Review	Tea	Colour, taste, aroma, appearance	Sensory attributes of tea include color, taste, aroma, and appearance, which are the key factors of tea quality as well as indicators of commercial values.

Publications	Aim	Type of study	Type of beverage	Quality attributes mentioned	Detail
Reflectance (NIR) Spectroscopy and Chemometrics. *Journal of Spectroscopy, 2019*.	for the quality control of tea, including the measurement of chemical compositions, the evaluation of sensory attributes, the identification of categories and varieties, and the discrimination of geographical origins.				TFs and thearubigins (TRs) are the major pigments that determine the color and brightness of black tea infusion. During the fermentation process, the color of black tea leaves changes remarkably from green to red and then to brown When the TRs/TFs ratio is approximately equal to 10 :1, the fermentation process of black tea reaches the optimum point, and the most beautiful color was produced in tea infusion. 5e TRs/TFs ratio thus is a critical parameter for evaluating the fermentation degree and sensory quality characteristics of black tea.
Alvarez, V. B. (2009). Fluid milk and cream products. In *The sensory evaluation of dairy products* (pp. 73-133). Springer, New York, NY.		Book chapter	Fluid milk	Flavour, mouthfeel, homogenity, rancidity	-Milk has almost a neutral flavor profile that is pleasantly sweet, with no distinct aftertaste. The flavor is imparted by the natural components such as proteins, fat, salts, milk sugar (lactose), and possibly small amounts of other milk components. -Milkfat is responsible for the ‘‘rich’’ mouthfeel of full fat milk in comparison to skim milk. -The mixed sample should also be perfectly homogeneous (i.e., exhibit no buttery particles or graininess). -Milk will develop off-flavors, described as hydrolytic rancidity, fruity/fermented, unclean-like, and/or bitter, due to the growth and metabolism of various microbial contaminants.
Hurtado, A., Guàrdia, M. D., Picouet, P., Jofré, A., Ros, J. M., & Bañón, S. (2017). Stabilisation of red fruit-based smoothies by high-pressure processing. Part II: effects on sensory quality and selected nutrients. *Journal of the Science of Food and Agriculture*, *97*(3), 777-783.	...was to compare the effects of two industrial treatments (HPP at 350 MPa for 5 min and a thermal treatment at 85 ∘C for 7 min) on the sensory stability and retention of major nutrients of red-fruit based smoothies kept in retailing conditions.	Empirical	Red fruit-based juice	Freshness (shelf-life), flavour, viscosity/ density	-In our study, the loss of sensory quality began to be relevant at 21 days of chill storage and, therefore, ‘fresh-like’ red fruit-based smoothies, free of marmalade flavour, could be offered to consumers for at least 14 days. -Smoothies containing the complete fruit pulp are more dense and viscous than the equivalent juices.
Eissa, H. A., Yaseen, A. A., Bareh, G. F., Ibrahim, W. A., & Mansour, A. F. (2018). Enhancing Aroma Flavor, Bio-Active Constituents and Quality Attributes of Cantaloupe Juice Supplementing with Wheat Grass Juice. *Journal of Biological Sciences*, *18*(1), 1-12.	The objective of this research was to evaluate the fortification of traditional CJ with WGJ to produce healthy juice and maintaining, at the same time freshly color, texture, taste and flavor juice.	Empirical	Cantaloupe juice	Colour, odour, taste	From the point of view for consumers, the color, odor and taste of fruit juice was very significant because it evaluate the marketability of juice. Furthermore, the flavored and diluted forms of the WGJ were found to display an acceptable sensory profile inclusive color, taste and aroma.
Total relevant publications: 27					

Possible quality deviations (step 3B)

Publications	Aim	Type of study	Type of beverage	Possible quality deviations	Type of deterioration	Quality attributes affected (from the paper)
Silva, N. K. V. D., Sabino, L. B. D. S., Oliveira, L. S. D., Torres, L. B. D. V., & Sousa, P. H. M. D. (2016). Effect of food additives on the antioxidant properties and microbiological quality of red guava juice. *Revista Ciência Agronômica*, *47*(1), 77-85.	This study aimed to evaluate the influence of different chemical food preservatives, isolated and / or associates, on antioxidant activity and microbiological and sensory attributes of guava juice sweetened during storage.	Empirical	Red guava juice	Oxidation	Chemical	Appearance (colour), flavour (taste, aroma)
				Non-enzymatic browning		Appearance (colour)
				Microbial spoilage	Microbiological	Flavour (taste, aroma), shelf-life
Evrendilek, G. A., Celik, P., Agcam, E., & Akyildiz, A. (2017). Assessing impacts of pulsed electric fields on quality attributes and furfural and hydroxymethylfurfural formations in apple juice. *Journal of food process engineering*, *40*(5), e12524.	...to quantify and compare effects of changing the processing variables of electric field strength, treatment time, temperature, and energy on physical properties, bioactive compounds, and formations of furfural and HMF for PEF processed apple juice,	Empirical	Apple juice	Enzymatic & non-enzymatic browning	Chemical	Appearance (colour)
				Oxidation		
Tomadoni, B., Cassani, L., Viacava, G., Moreira, M. D. R., & Ponce, A. (2017). Effect of ultrasound and storage time on quality attributes of strawberry juice. *Journal of Food Process Engineering*, *40*(5), e12533.	...to determine the effect of ultrasound treatment in comparison with thermal treatment on the physico-chemical properties (color, total soluble solids, and total acidity), microbial growth, total phenolic content, and antioxidant activity (DPPH) of strawberry juice during shelf life.	Empirical	Strawberry juice	Microbial spoilage	Microbiological	Appearance (colour), texture, flavour (taste, aroma), shelf-life
Falade, K. O., Babalola, S. O., Akinyemi, S. O. S., & Ogunlade, A. A. (2004). Degradation of quality attributes of sweetened Julie and Ogbomoso mango juices during storage. *European Food Research and Technology*, *218*(5), 456-459.	...to study the changes in colour and ascorbic acid loss, and other chemical attributes of sweetened mango juices, from Ogbomoso and Julie varieties during storage under ambient (25°C) conditions.	Empirical	Mango juice	Non-enzymatic browning	Chemical	Appearance (colour), flavour (taste, aroma)
Huvaere, K., & Skibsted, L. H. (2015). Flavonoids protecting food and beverages against light. *Journal of the Science of Food and Agriculture*, *95*(1), 20-35.	The aim of this review is to evaluate the feasibility of flavonoids protecting foods and beverages against harmful photochemistry.	Review	Food and beverages (milk)	Oxidation	Chemical	Flavour (taste, aroma), appearance (colour), shelf-life
				Degradation of compounds (amino acid)		Flavour (aroma)

Publications	Aim	Type of study	Type of beverage	Possible quality deviations	Type of deterioration	Quality attributes affected (from the paper)
Martin, N., Carey, N., Murphy, S., Kent, D., Bang, J., Stubbs, T., ... & Dando, R. (2016). Exposure of fluid milk to LED light negatively affects consumer perception and alters underlying sensory properties. *Journal of dairy science*, *99*(6), 4309-4324.	This study is the first to demonstrate the effects of LED lighting on consumer perception of fluid milk.	Empirical	Fluid milk	Microbial spoilage	Microbiological	Flavour (taste, aroma), appearance (colour), texture
Alvarez, V. B. (2009). Fluid milk and cream products. In *The sensory evaluation of dairy products* (pp. 73-133). Springer, New York, NY.		Book chapter	Fluid milk	Microbial spoilage	Microbiological	Flavour (taste, aroma), appearance (colour), texture, shelf-life
				Oxidation	Chemical	Flavour (taste, aroma), shelf-life
				Degradation of compounds (amino acid)	Chemical	Flavour (taste, aroma)
				Non-enzymatic browning	Chemical	Appearance, flavour (taste, aroma), shelf-life
Fazaeli, M., Hojjatpanah, G., & Emam-Djomeh, Z. (2013). Effects of heating method and conditions on the evaporation rate and quality attributes of black mulberry (Morus nigra) juice concentrate. *Journal of food science and technology*, *50*(1), 35-43.	The present study was carried out to investigate the effect of microwave heating of black mulberry juice on quality parameters and to compare it with a conventional heating system under similar processing conditions.	Empirical	Black mulberry juice	Non-enzymatic browning	Chemical	Appearance (colour)
Wiking, L., Frøst, M. B., Larsen, L. B., & Nielsen, J. H. (2002). Effects of storage conditions on lipolysis, proteolysis and sensory attributes in high quality raw milk. *Milchwissenschaft*, *57*(4), 190-194.	...to study whether storage of high quality raw milk at 4 and 8ºC affect proteolysis, lipolysis, and sensory attributes during 72h.	Empirical	Raw milk	Microbial spoilage	Microbiological	Texture, flavour (taste, aroma), shelf-life
				Degradation of compounds (fat and protein)	Chemical	Flavour (taste, aroma)
Li, J., Miao, S., & Jiang, Y. (2009). Changes in quality attributes of longan juice during storage in relation to effects of thermal processing. *Journal of food quality*, *32*(1), 48-57.	This work was aimed at investigating the changes in quality attributes of longan juice in relation to the effects of heat treatment.	Empirical	Longan juice	Enzymatic & non-enzymatic browning	Chemical	Appearance (turbidity, colour)
Caminiti, I. M., Palgan, I., Muñoz, A., Noci, F., Whyte, P., Morgan, D. J., ... & Lyng, J.	...to examine whether UV irradiation could be used as an	Empirical	Apple juice	Enzymatic browning	Chemical	Appearance (colour)

Publications	Aim	Type of study	Type of beverage	Possible quality deviations	Type of deterioration	Quality attributes affected (from the paper)
G. (2012). The effect of ultraviolet light on microbial inactivation and quality attributes of apple juice. *Food and Bioprocess Technology*, *5*(2), 680-686.	alternative treatment to mitigate adverse effects on quality.					
Chia, S. L., Rosnah, S., & Noranizan, M. A. (2012). The effect of storage on the quality attributes of ultraviolet-irradiated and thermally pasteurised pineapple juices.	The objective of this study was to investigate the effect of storage time on the quality of UV-irradiated pineapple juice compared with thermal pasteurisation which is the conventional technology.	Empirical	Pineapple juice	Microbial spoilage	Microbiological	Shelf-life, flavour (taste, aroma), texture, appearance (turbidity)
				Oxidation	Chemical	Appearance (colour), flavour (taste, aroma)
				Non-enzymatic browning	Chemical	Appearance (colour)
Tastan, O., & Baysal, T. (2015). Clarification of pomegranate juice with chitosan: changes on quality characteristics during storage. *Food chemistry*, *180*, 211-218.	...to determine the effects of the process temperature, and process time on the turbidity and a⁄ values of juice, and to compare the quality characteristics of PJ during storage at 4 and 20 C for 6 months.	Empirical	Pomegranate juice	Degradation of compounds (anthocyanins)	Chemical	Appearance (colour)
Agcam, E., Akyildiz, A., & Evrendilek, G. A. (2016). A comparative assessment of long-term storage stability and quality attributes of orange juice in response to pulsed electric fields and heat treatments. *Food and bioproducts processing*, *99*, 90-98.	The objectives of the present study were to comparatively quantify effects of PEF versus heat treatments on storage stability and critical quality variables of orange juice for 180 days at 4 ◦C estimating degradation kinetics of ascorbic acid, and formation kinetics of hydroxyl methyl furfural (HMF).	Empirical	Orange juice	Non-enzymatic browning	Chemical	Flavour (taste, aroma), Appearance (colour), shelf-life
				Microbial spoilage	Microbiological	Shelf-life, flavour (taste, aroma)
González, E., Vegara, S., Martí, N., Valero, M., & Saura, D. (2015). Physicochemical characterization of pure persimmon juice: nutritional quality and food acceptability. *Journal of food science*, *80*(3), C532-C539.	The objectives of this research work were: first, the preparation of pure persimmon juice from fruits of "Rojo Brillante" cultivar grown in Spain and second, the study of physicochemical changes in the resulting juice due to the processes of pasteurization and storage.	Empirical	Persimmon juice	Non-enzymatic browning	Chemical	Appearance (colour)
Bajwa, U., & Mittal, S. (2015). Quality characteristics of no added sugar ready to drink milk supplemented with mango pulp. *Journal of food science and technology*, *52*(4), 2112-2120.	The main objectives of the study therefore, were to optimize the level of mango pulp in sugar substituted low fat milk drink and to study the physico-chemical characteristics, sensory quality and shelf life of the prepared product.	Empirical	Milk + mango pulp	Microbial spoilage	Microbiological	Texture
Total relevant publications: 16						

Technological/ managerial factors influencing quality attributes and CQPs (step 4-5)

Factor	Process activity	Quality attribute affected	Mechanism	CQP (Yes/No)	Publications
Technological					
Light	All	Colour, flavour (taste, aroma)	Light can penetrate the packaging material and act on product giving rise to an enhanced oxidative status (with the formation of carbonylcompounds (hexanal, pentanal, heptanal) and dimethyldisulphide, products of light-induced oxidation in light-exposed containers).	Yes	Martin, N., Carey, N., Murphy, S., Kent, D., Bang, J., Stubbs, T., ... & Dando, R. (2016); Tobolková, B., Durec, J., Belajová, E., Mihalíková, M., Polovka, M., Suhaj, M., Daško, L., & Šimko, P. (2013); Intawiwat, N., Pettersen, M. K., Rukke, E. O., Meier, M. A., Vogt, G., Dahl, A. V., ... & Wold, J. P. (2010); Kontominas, M. (2010); Karatapanis, A. E., Badeka, A. V., Riganakos, K. A., Savvaidis, I. N., & Kontominas, M. G. (2006); Conrad, K. R., Davidson, V. J., Mulholland, D. L., Britt, I. J., & Yada, S. (2005); Mestdagh, F., De Meulenaer, B., De Clippeleer, J., Devlieghere, F., & Huyghebaert, A. (2005).
Temperature	Pasteurization	Appearance (colour), flavour (aroma, taste), texture	Enzyme activity after processing, particularly for peroxidase (higher thermal resistance) may be responsible for the color changes observed or the increase of NEB values (effect of Maillard reaction).	Yes	Hajar-Azhari,S., Shahruddin, R., & Rahim, M. (2018); Wang, P., Zhan, P., Tian, H., Zhang, F., & Xi, J. (2018); Kunitake, M., Ditchfield, C., Silva, C., & Petrus, R. (2014); Bhattacherjee, A. K., Tandon, D. K., Dikshit, A., & Kumar, S. (2011); Kontominas, M. (2010).
	Filling	Flavour (taste, aroma)	The higher concentrations of furancarboxaldehyde might be based on the higher thermal treatment during the hot-fill process. Furancarboxaldehyde has been reported to be partly responsible for the formation of off-flavour in fruit juices and is generally regarded to be a good indicator for thermally treated juices.	Yes	Siegmund, B., Derler, K., & Pfannhauser, W. (2004).
	Storage-distribution	Appearance (colour), flavour (aroma, taste), texture	The increase of storage temperature will cause (1) variation of odor-active compounds, (2) increase in their furfural, hydroxymethyl furfural, furfural, and non-enzymatic browning and a consistent decline in acidity, total sugars, ascorbic acid, amino acids, and phenols, and (3) because the diffusion coefficient of the compounds also increase, the amount of compound absorption into packaging materials then increase.	Yes	Marsol-Vall, A., Laaksonen, O., & Yang, B. (2019); Kaddumukasa, P. P., Imathiu, S. M., Mathara, J. M., & Nakavuma, J. L. (2017); Oliveira, A. D. N., Ramos, A. M., Minim, V. P. R., & Chaves, J. B. P. (2012); Bhattacherjee, A. K., Tandon, D. K., Dikshit, A., & Kumar, S. (2011); Beltrán, F., Perez-Lopez, A. J., Lopez-Nicolas, J. M., & Carbonell-Barrachina, A. A. (2009); Esteve, M. J., Frígola, A., Rodrigo, C., & Rodrigo, D. (2005); Sharma, S. K.,

Factor	Process activity	Quality attribute affected	Mechanism	CQP (Yes/No)	Publications
					Kaushal, B. B., & Sharma, P. C. (2004); Simon, M., & Hansen, A. P. (2001).
Time	Pasteurization	Appearance (colour), flavour (aroma, taste), texture	Excessive sterilization/ heat treatment caused decreases in esters with generation of dimethyl sulfoxide resulting warmed-over flavour.	Yes	Weber, F., & Larsen, L. R. (2017); Karmakar, R., Ghosh, A. K., & Gangopadhyay, H. (2011); Kontominas, M. (2010).
	Storage-distribution	Appearance (colour), flavour (aroma, taste), texture	The early Maillard reaction slowly develops, resulting in a 50% increase in furosine, protein denaturation increases and some casein proteolysis occurs. Finally, oxidation-sensitive pigment/ compound (e.g. vitamin C) is highly dependent on storage time.	Yes	Oliveira, A. D. N., Ramos, A. M., Minim, V. P. R., & Chaves, J. B. P. (2012); Gliguem, H., & Birlouez-Aragon, I. (2005); Sharma, S. K., Kaushal, B. B., & Sharma, P. C. (2004); Burdurlu, H. S., & Karadeniz, F. (2003).
Microbial load	All	Appearance (colour), flavour (aroma, taste), texture	pH, Brix, titratable acidity (%)—all decreased probably due to the high microbial load, resulting in biodeterioration, spoilage, and shortened storage stability of juices.	Yes	Martin, N. H., Boor, K. J., & Wiedmann, M. (2018); Kaddumukasa, P. P., Imathiu, S. M., Mathara, J. M., & Nakavuma, J. L. (2017); Chavan, R. S., Chavan, S. R., Khedkar, C. D., & Jana, A. H. (2011); Kontominas, M. (2010); Simon, M., & Hansen, A. P. (2001).
Oxygen	All	Appearance (colour), flavour (aroma, taste), texture	Deterioration of juices (ascorbic acid degradation and darkening of color) was triggered by the rise in oxygen in the headspace of the storage containers as the factor of oxidation. Oxygen also can trigger spoilage by certain microflora.	Yes	Kontominas, M. (2010); Beltrán, F., Perez-Lopez, A. J., Lopez-Nicolas, J. M., & Carbonell-Barrachina, A. A. (2008).
Packaging material	All	Appearance (colour), flavour (aroma, taste), texture	-The greater wall thickness could allow less oxygen transmission to the juice, which could reduce the rates of the microbial growth, color change and flavor degradation in the juice. -The triple-layer plastic mini bottle with black coloured and completely opaque intermediate layer offered the best protection against lipid oxidation. -Packaging must protect milk from atmospheric oxygen but also from light. Lastly, packaging should be substantially inert in terms of interaction with milk in order to avoid migration phenomena (transfer of packaging components into the milk) or flavor-scalping phenomena (absorption of desirable flavor components of milk by the packaging material).	Yes	Min, S. C., Zhang, H. Q., & Yang, H. J. (2011); Intawiwat, N., Pettersen, M. K., Rukke, E. O., Meier, M. A., Vogt, G., Dahl, A. V., ... & Wold, J. P. (2010); Kontominas, M. (2010); Beltrán, F., Perez-Lopez, A. J., Lopez-Nicolas, J. M., & Carbonell-Barrachina, A. A. (2009); Karatapanis, A. E., Badeka, A. V., Riganakos, K. A., Savvaidis, I. N., & Kontominas, M. G. (2006); Gliguem, H., & Birlouez-Aragon, I. (2005); Mestdagh, F., De Meulenaer, B., De Clippeleer, J., Devlieghere, F., & Huyghebaert, A. (2005); Moyssiadi, T., Badeka, A., Kondyli, E., Vakirtzi, T., Savvaidis, I., & Kontominas, M. G. (2004); Zygoura, P., Moyssiadi, T., Badeka, A., Kondyli, E., Savvaidis, I., & Kontominas, M. G. (2004).

Factor	Process activity	Quality attribute affected	Mechanism	CQP (Yes/No)	Publications
Managerial					
Procedures	All	Appearance (colour), flavour (aroma, taste), texture	Many factors contribute to the occurence of PPC in fluid milk, including problems with cleaning and sanitation procedures. The procedures will influence how people work including what should be focused in the manufacturing steps.	Yes	Martin, N. H., Boor, K. J., & Wiedmann, M. (2018); Dudeja, P., & Singh, A. (2017); Martínez-Gonzáles, N. E., & Castillo, A. (2016).
Production control	Filling-pasteurization	Appearance (colour), flavour (aroma, taste), texture	-To ensure the quality of the beverages, the safety of the components of products from being contaminated is to be checked and all the processes by following the steps of beverage testing procedure such as checking the leakage of bottles, packaging, all potables, and the product properties. -Process control strategies involve managing the temperature via proper handling of product's temperature, its processing environment temperature, and temperature control throughout the production unit or chain. -Regular inspection of work tables, tools, work clothes, and operators' hands should be executed, and microbial sampling tests (aerobic bacterial count and coliform bacteria) of the final products after packaging and other products should be conducted.	Yes	Aadil, R. M., Madni, G. M., Roobab, U., ur Rahman, U., & Zeng, X. A. (2019); Baruffaldi, G., Accorsi, R., Santi, D., Manzini, R., & Pilati, F. (2019); Berk, Z. (2016); Shan, Y. (2016).
Storage and distribution control	Storage-distribution	Appearance (colour), flavour (aroma, taste), texture	- Where necessary, conveyances and bulk containers shall be designed and constructed so that they do not contaminate foods or packaging, can be effectively cleaned, and when necessary disinfected. It should permit effective separation of different food or food from nonfood items during transport; and provide effective protection from contamination including dust and dirt. There should be maintenance of effective temperature, humidity, and other conditions necessary to protect food from harmful or undesirable microorganisms. - The temperature records in the warehouse should be maintained (and humidity records when necessary).	Yes	Aadil, R. M., Madni, G. M., Roobab, U., ur Rahman, U., & Zeng, X. A. (2019); Martínez-Gonzáles, N. E., & Castillo, A. (2016).
Compliance of employees	All	Appearance (colour), flavour (aroma, taste), texture	These should be controlled by adopting proper sanitation, good agriculture practices (GAPs), GMPs, good hygiene practices (GHPs), and proper hazard analysis system (ISO, HACCP) within the food processing area, and an adequate follow-up of standard operating procedures (SOPs) and sanitation standard operating procedures (SSOPs). The compliance of operators to those standards and procedures is crucial.	Yes	Aadil, R. M., Madni, G. M., Roobab, U., ur Rahman, U., & Zeng, X. A. (2019); Dudeja, P., & Singh, A. (2017).
Total relevant publications: 35					

Part B. Bio-based materials as beverage packaging

<table>
<tr><th>Publications</th><th>Aim</th><th>Type of study</th><th>Type of beverage</th><th>Type of bio-based materials</th><th>Properties/ characteristics</th></tr>
<tr><td>Haugaard, V., Weber, C., Danielsen, B., & Bertelsen, G. (2002). Quality changes in orange juice packed in materials based on polylactate. European Food Research and Technology, 214(5), 423-428.</td><td>This study was undertaken in order to determine the impact of three different packaging materials (PLA compared to the conventional HDPE and PS) on quality changes in fresh, unpasteurised orange juice.</td><td>Empirical</td><td>Orange juice</td><td>PLA</td><td>-The present study demonstrates that a rigid packaging material based on polylactate (PLA) was at least as effective as conventional high density polyethylene (HDPE) and polystyrene (PS) packaging materials in protecting fresh, unpasteurised orange juice against quality changes. Fresh, unpasteurised orange juice was stored in PLA, HDPE, and PS at 4 °C for 14 days. Quality changes were evaluated by determination of colour stability, ascorbic acid (AA) degradation, and sorption of limonene by the polymers (scalping). Results showed a significantly greater loss of AA in orange juice stored in HDPE and PS compared to PLA, significantly less colour changes of orange juice stored in PLA and PS than in HDPE, and no detectable limonene scalping into PLA and PS, as opposed to a high degree of scalping into HDPE.
-The pronounced decrease in oxygen headspace and the corresponding decrease in carbon dioxide concentrations might be explained by growth of yeasts and moulds, since the orange juice was unpasteurised. The suggested growth, of yeasts especially, was further verified after 7 days of storage where the orange juice had an unacceptable fermented odour.</td></tr>
<tr><td rowspan="2">Pandit, P., Nadathur, G. T., Maiti, S., & Regubalan, B. (2018). Functionality and Properties of Bio-based Materials. In Bio-based Materials for Food Packaging (pp. 81-103). Springer, Singapore.</td><td rowspan="2"></td><td rowspan="2">Book chapter</td><td rowspan="2"></td><td>PLA</td><td>-PLA, discovered in 1845, is the only melt-processable fibre from annually renewable natural resources such as cornstarch, tapioca or sugarcane
-PLA is subsequently modified, as required, and drawn into fibres, cast as films or moulded into plastic products like bottles. The favourable properties of the bioplastic, PLA fibres are strong and durable, and their fabric has good drape and UV resistance. The limiting oxygen index (25) is higher than that of PET. It has low water uptake (0.4–0.6%) but greater than that of PET and PP.
PLA also used for orange juice packaging , with combination with nisin, it has antimicrobial activity: significantly inhibit the growth of L.monocytogenes.
Table 1 Characteristics of amorphous PLA<table><tr><th>Characteristics</th><th>Unit</th><th>PLA</th></tr><tr><td>Glass transition temperature (Tg)</td><td>(°C)</td><td>62.1 ± 0.7</td></tr><tr><td>Melting temperature (Tm)</td><td>(°C)</td><td>195–245</td></tr><tr><td>Enthalpy</td><td>(ΔH^c_m) ($J\ g^{-1}$)</td><td>93–148</td></tr><tr><td>Percent crystallinity</td><td>%</td><td></td></tr><tr><td>Density (ρ)</td><td>(g/cm^3)</td><td>1.36</td></tr><tr><td>Solubility</td><td>–</td><td>Dichloromethane, acetonitrile, chloroform</td></tr><tr><td>Degradation</td><td>–</td><td>Hydrolysis (random nonenzymatic, enzymatic by microbes)</td></tr><tr><td>Molecular weight (Mw)</td><td>(kDa)</td><td>66</td></tr><tr><td>Stereoisomer</td><td>–</td><td>L-lactic acid</td></tr><tr><td>O_2 permeability</td><td>$cm^3\ mil/m^2$</td><td>550</td></tr><tr><td>CO_2 permeability</td><td>$cm^3\ mil/m^2$</td><td>3000</td></tr><tr><td>Water vapor transmission</td><td>$g{\cdot}\mu m{\cdot}kPa^{-1}{\cdot}m^{-2}{\cdot}d^{-}$</td><td>161–237</td></tr><tr><td>Tensile modulus (E)</td><td>(GPa)</td><td>3500</td></tr><tr><td>Tensile strength (σ)</td><td>(MPa</td><td>48–53</td></tr><tr><td>Elongation at break</td><td>(%)</td><td>7</td></tr><tr><td>Percent of elongation</td><td>(%)</td><td>12</td></tr><tr><td>Transmission</td><td>(230–250 nm)</td><td>95%</td></tr><tr><td>Thermal conductivity</td><td>(190 °C</td><td>0.195</td></tr></table></td></tr>
<tr><td>Bio-PE</td><td>Bio-based polyethylene has identical physical, chemical and mechanical properties to petrochemical polyethylene.</td></tr>
<tr><td>Rudnik, E. (2013). Compostable polymer properties and packaging applications. In Plastic Films in Food</td><td></td><td>Book chapter</td><td></td><td>PLA</td><td>-PLA polymers range from amorphous glassy polymers with a glass transition temperature of about 5060C to semicrystalline products with melting points ranging from 130C to 180C.
-PLA has good mechanical properties, thermal plasticity and biocompatibility, is readily fabricated, and is thus a promising polymer for various end-use applications. From a</td></tr>
</table>

Publications	Aim	Type of study	Type of beverage	Type of bio-based materials	Properties/ characteristics
Packaging (pp. 217-248). William Andrew Publishing.					physical property standpoint, it is often loosely compared to polystyrene (PS). Like PS, standard-grade PLA has high modulus and strength and is lacking in toughness. The toughness of PLA can be dramatically improved through orientation, blending, or copolymerization. -PLA is an inherently polar material due to its basic repeated unit of lactic acid. This high polarity leads to a number of unique attributes such as high critical surface energy that yields excellent printability. Another benefit of this polar polyester polymer is its resistance to aliphatic molecules such as oils and terpenes. -Possible application of PLA in liquid and juice packaging was suggested based on permeability studies of a variety of polymers to D-limonene, a major component of orange juice flavor. Upon testing, no D-limonene could be detected passing through the PLA film. -PLA films have better UV light barrier properties than low-density polyethylene (LDPE), but they are slightly worse than those of cellophane, PS and poly(ethylene terephthalate) (PET). PLA films have mechanical properties comparable to those of PET and better than those of PS. The CO2, O2, and water permeability coefficients of PLA are lower than those of PS and higher than those of PET.
Coles, R., & Kirwan, M. J. (Eds.). (2011). *Food and beverage packaging technology* (p. 303). Hoboken, NJ: Wiley-Blackwell.		Book		PLA	-PLA has high transparency and surface gloss together with other physico-chemical characteristics such as good chemical resistance to fats and oils. These enable the material to be an alternative to PET, HIPS, PVC, and cellulosics in some packaging where high clarity is essential. -In addition to forming a flavour and aroma barrier comparable to PET, PLA readily accepts coatings, inks and adhesives and can be thermo-laminated to paper or paperboards. Other applications include PLA film used for the windows of sandwich cartons, PLA bottles for beverages and thermo-formed PLA trays for fresh produce, salads and coleslaw. -PLA is rigid, brittle and likely to deform at temperature in excess of its low glass transition temperature of ∼55◦C. -Until recently, PLA could not be used for hot-fill and gaseous drinks like beer and cola. However, development work is being conducted to address this. In 2007, Purac – a subsidiary of CSM (Netherlands, www.purac.com) — announced its patented PLA polymers that withstand temperatures of at least 175◦C. This new development enables its use in more widespread applications such as hot fill bottles, microwaveable trays, temperature resistant fibres, electronics and automotive parts. - PLA can also be sourced from other products, such as sugar beet, tapioca and sugar cane, corn. - PLA is compostable in industrial composting facilities - PLA's most common applications are in areas such as fresh food packaging and short shelf life products that do not require sophisticated barriers
				(Bio)-PE	-Braskem, a Brazilian thermoplastic resin manufacturer, has developed a 200 kt/annual capability to produce PE from the polymerization of ethylene derived from ethanol by fermentation of sugar cane. - PE is non-compostable.

Publications	Aim	Type of study	Type of beverage	Type of bio-based materials	Properties/ characteristics
					- Polyethylenes are readily heat sealable. They can be made into strong, tough films, with a good barrier to moisture and water vapour. They are not a particularly high barrier to oils and fats or gases, such as carbon dioxide and oxygen compared with other plastics, although barrier properties increase with density. The heat resistance is lower than that of other plastics used in packaging, with a melting point of around 120◦C, which increases as the density increases. - PE and other plastics are also used in combination with paperboard to make the base material for liquid packaging cartons.
				PET	- There are many different types of polyester, depending on the monomers used. When terephthalic acid reacts with ethylene glycol and polymerises, the result is PET. - Polyesters have much higher heat resistance than many plastics and, when oriented, have very high mechanical strength. - PET melts at a much higher temperature than PP, typically 260◦C, and due to the manufacturing conditions does not shrink below 180◦C. This means that PET is ideal for high-temperature applications using steam sterilisation, boil in-the-bag and for cooking or reheating in microwave or conventional radiant heat ovens. - PET is a medium oxygen barrier on its own but becomes a high barrier to oxygen and water vapour when metallised with aluminium. - PET film provides strength and puncture resistance. - PET is the fastest growing plastic for food packaging applications as a result of its use in all sizes of carbonated soft drinks and mineral water bottles that are produced by injection stretch blow moulding. PET bottles are also used for edible oils, as an alternative to PVC.
Cooper, T. A. (2013). Developments in bioplastic materials for packaging food, beverages and other fast-moving consumer goods. In *Trends in Packaging of Food, Beverages and Other Fast-Moving Consumer Goods (FMCG)* (pp. 108-152). Woodhead Publishing.		Book chapter		PLA	-Commercial PLA is a highly transparent, glossy rigid thermoplastic with many attractive properties for film, sheet, thermoformed, injection- and blow- molded products and fibers, lying between crystal polystyrene and PET. It has high tear strength like polystyrene and is easily printable and sealable. However, a major disadvantage is its low glass transition temperature (Tg) (~57°C) and significantly lower temperature resistance than PET, since the heat distortion temperature of the poly-L-lactide is about 60°C, making it unsuitable for hot- cup applications. This can be increased up to about 190°C by the incorporation of fillers or nucleating agents, blending with other polymers. -PLA shows a poor barrier towards oxygen, carbon dioxide and moisture vapor, although it provides a high flavor and aroma barrier and high resistance to grease and oil. Although the gas barrier properties can be improved by plasma SiOx deposition, they are still not as good as PET. -Polylactic acid (PLA) packaging films have had major problems of brittleness, thermal stability and high processing costs and can be unacceptably noisy due to the PLA stiffness and crystallinity. -PLA is not a good polymer for bottles compared with PET, because of its poor barrier properties, low heat distortion temperature. - Currently, biodegradable and compostable polymers, like PLA, are mostly used for products with short shelf life and storage times

Publications	Aim	Type of study	Type of beverage	Type of bio-based materials	Properties/ characteristics
					- PLA is compostable under industrial composting conditions (EN 13432, ASTM D-6400),24 but not by home composting, and it is not readily anaerobically digestible, soil biodegradable or marine biodegradable. - Commercial PLA has suffered from poor processability and low melt strength at the extrusion temperature of 180–210°C, which is considerably lower than for conventional polymers - Other initial problems with PLA have included: - Brittleness, poor impact strength and low temperature flexibility - High sensitivity to hydrolysis by atmospheric moisture
				Bio-PET	-The biobased PET is chemically identical to the petrochemical plastics.
Garcia, M. S., & Lagaron, J. M. (2012). Nanocomposites for food and beverage packaging materials. In *Nanotechnology in the Food, Beverage and Nutraceutical Industries* (pp. 335-361). Woodhead Publishing.		Book chapter		PLA	Of particular interest in food packaging is PLA due to its excellent transparency and relatively good water resistance. The water permeability of PLA is for instance much lower than that of proteins and polysaccharides but it is still higher than that of conventional polyolefins and PET. Its relatively high stiffness is usually reduced by the addition of plasticizers such as PCL and others but these also lead to a decrease in oxygen barrier and in transparency. The main drawbacks of this polymer in terms of its performance are still its low thermal resistance, excessive brittleness and the fact it is a less effective (and sometimes inefficient) barrier to oxygen and water compared to for instance other benchmark packaging polymers like PET.
Total relevant publications: 6					

Appendix C – Introduction letter

Dear *(name of the company)* Team,

My name is Ni Putu Intan Sawitri Wirayani (Intan). I am a second-year master student of Food Quality Management at Wageningen University and Research (WUR), NL.

Currently, I am conducting a master thesis on investigating the quality deviations and control of milk and juices packaged with alternative packaging materials (bio-based/ plant-based). I got information about *(name of the product)* in bio-based packaging from the web page below, and I think it is relevant enough to be followed up.

(related webpage)

Would you (from Quality or Packaging R&D dept) please help to share your experience? It will take more/ less 30-45 minutes in a flexible schedule via Skype/ phone call. If you want, I can also send the questions first so that we can discuss it together later. Your answer will only be used for educational purposes. I highly appreciate your help since there are still a few beverage companies implementing these kinds of packaging.

I am looking forward to hearing from you :)

Thank you.
Best regards,
Intan

Appendix D – Questionnaire for experts

The questionnaire is expected to be answered by the employee(s) with a background or working experience related to quality control and assurance or packaging development. Besides, it is also applicable for employee(s) that in his/ her jobs, she/ he needs to concern about product quality. In total, there are 3 parts of the questionnaire. The answers will be used only for educational purposes. The identity of the interviewee and the company will not be disclosed 😊

General information
What is your position in this company?
How many years have you worked in this company?
What is your job description in general?
How many years have you experienced in handling/ testing/ dealing with the product in bio-based packaging?
Could you please tell one moment that you contributed to the project related to bio-based packaging?

1. For milk/ juice companies which are already using bio-based plastic packaging

Part 1. The change of product packaging from conventional to bio-based materials		
1	When did your company decide to change the materials into the bio-based ones?	
2	What are the reasons for your company to change from conventional to bio-based packaging?	
3	When did your company start implementing bio-based packaging for the product(s)?	
4	Could you please explain the major changes in general when your company changed from conventional to bio-based packaging? (process/ machines/ quality control activities/ etc)	
5	Could you please explain the challenges that your company had faced in implementing bio-based packaging?	
Part 2. Bio-based materials for milk/ juices packaging		
6	Which product(s) of your company is packaged with bio-based packaging and in which form of packaging (bottle/ multi-layered cartons/ etc.)? (e.g., nectar in a plastic bottle; whole milk in multi-layered cartons, etc.)	
7	What is the bio-based plastic(s) used for product packaging?	
8	In which part is the bio-based plastic(s) in the product packaging? (lid/ inner or outer plastic layer (30%/ 50%/ 100%)/ whole packaging/ etc)	
9	Do you know what the characteristics/ properties of this bio-plastic(s) are? If yes, please mention.	
10	Do you know what the strengths and weaknesses of this bio-based plastic(s) are? If yes, please mention.	
	Strength(s)	Weakness(es)

Part 3. Product quality with bio-based packaging	
11	How do you control the product quality (in primary and secondary packaging, storage, and distribution)? / What are quality control activities for the product?
12	Based on your experience in the company, is there any change/ difference in quality points that should be controlled before and after the implementation of bio-based packaging? (conventional vs. bio-based)
	If yes, what is the difference(s)?
	Before (conventional) | After (bio-based)
	If no, why?
13	What are the experienced quality deviations your company has faced so far when using bio-based material(s) for product packaging?
For the following 3 questions, please have a look at the attachment in the last page (blank framework) to give insight in answering questions.	
14	What are the quality points (= factors) that influence the product quality from the technological point of view and the reasons? *Technological refers to product/ process factors, technological/ environmental conditions, e.g., storage/ filling temperature-time, light, oxygen, packaging materials, etc.*
15	What are the quality points (= factors) that influence the product quality from the managerial point of view and the reasons? *Managerial refers to people factors, documents/ administrative conditions, e.g., quality control activities, people's commitment, compliance, procedures, etc.*
16	The quality points are identified as critical if they give IRREVERSIBLE AND UNACCEPTABLE (for consumers) CHANGES to product quality (appearance (including color)/flavor (taste and aroma)/ texture/ shelf-life). So, from the technological and managerial points of view you mentioned earlier, what are the critical ones?

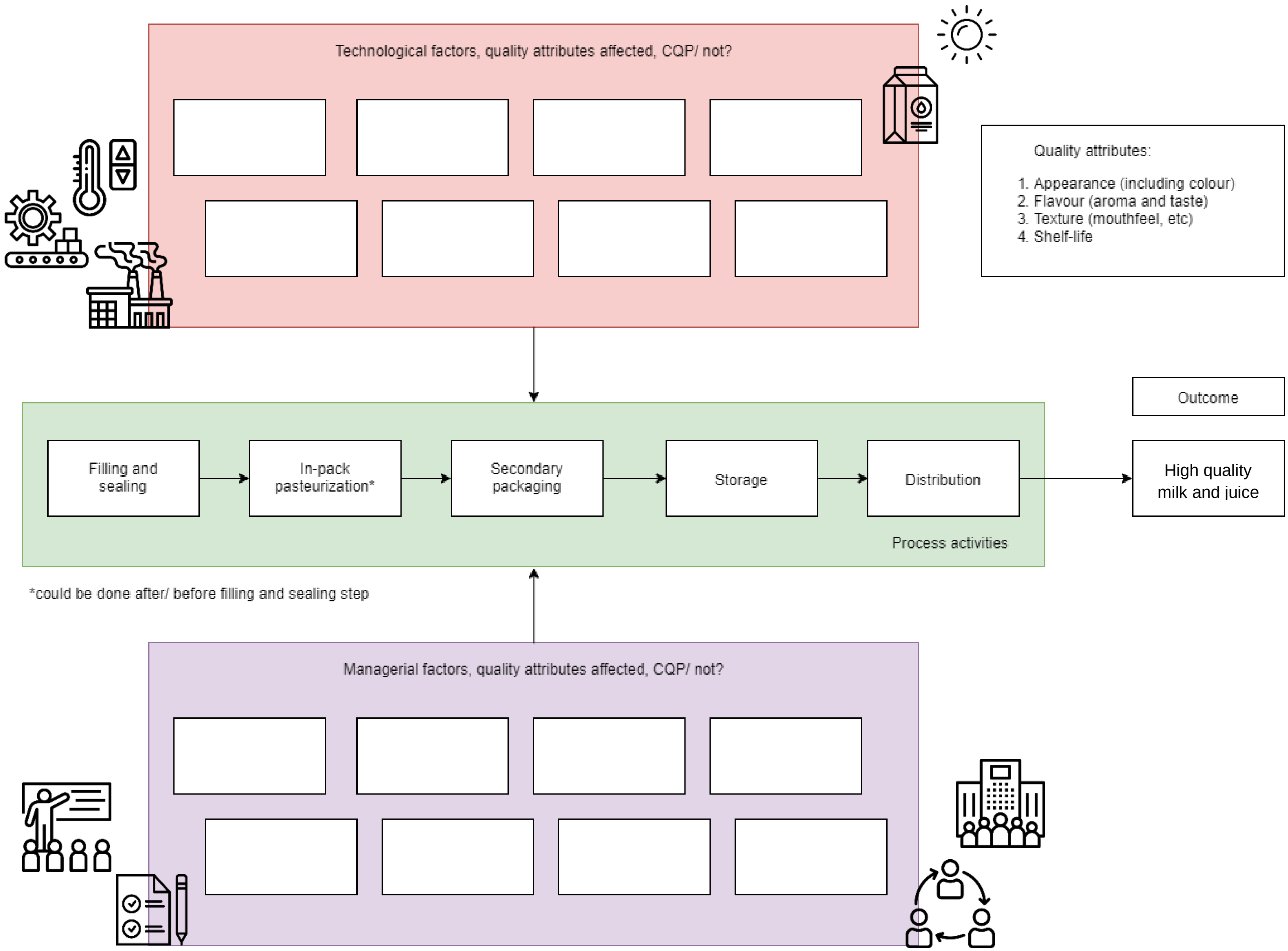
2. For beverage packaging companies which are routinely producing bio-based plastic packaging

Part 1. The change of product packaging from conventional to bio-based materials	
1	When did your company start implementing bio-based packaging?
2	Based on your knowledge, what are the reasons for a beverage company to change from conventional to bio-based packaging?
3	How long does it usually take for a beverage company from deciding to change into bio-based materials up to implementing the bio-based packaging? *(3 months, etc.)*
4	Could you please explain the major changes in general that should be considered by a beverage company when changing from conventional to bio-based packaging? *(process/ machines/ quality control activities/ etc.)*
5	Could you please explain the challenges that a beverage company usually face when implementing bio-based packaging?

Part 2. Bio-based materials for milk/ juices packaging		
6	Which product(s) is currently packaged with bio-based packaging from your company, and in which form of packaging (bottle/ multi-layered cartons/ etc.)? *(e.g., nectar in a plastic bottle; whole milk in multi-layered cartons, etc.)*	
7	What is the bio-based plastic(s) used for product packaging?	
8	In which part is the bio-based plastic(s) in the product packaging? *(lid/ inner or outer plastic layer (30%/ 50%/ 100%)/ whole packaging/ etc)*	
9	Could you please mention the characteristics/ properties of this bio-plastic(s) are?	
10	Could you please tell what the strengths and weaknesses of this bio-based plastic(s) are?	
	Strength(s)	Weakness(es)
Part 3. Product quality with bio-based packaging		
11	What are quality control activities for the product that you suggest to your customer (from packaging until storage and distribution)?	
12	From a packaging company point of view, is there any change/ difference in quality points that should be controlled before and after the implementation of bio-based packaging? (conventional vs. bio-based)	
	If yes, what is the difference(s)?	
	Before (conventional)	After (bio-based)
	If no, why?	
13	What are the experienced quality deviations related to the product (milk/ juice) reported to your company so far from your customers who are already using bio-based material(s) for their product packaging?	
For the following 3 questions, please have a look at the attachment in the last page (blank framework) to give insight in answering questions.		
14	What are the quality points (= factors) that influence the product quality from the technological point of view and the reasons? *Technological refers to product/ process factors, technological/ environmental conditions, e.g., storage/ filling temperature-time, light, oxygen, packaging materials, etc.*	
15	What are the quality points (= factors) that influence the product quality from the managerial point of view and the reasons? *Managerial refers to people factors, documents/ administrative conditions, e.g., quality control activities, people's commitment, compliance, procedures, etc.*	
16	The quality points are identified as critical if they give IRREVERSIBLE AND UNACCEPTABLE (for consumers) CHANGES to product quality (appearance (including color)/flavor (taste and aroma)/ texture/ shelf-life). So, from the technological and managerial points of view you mentioned earlier, what are the critical ones?	

Attachment

The blank framework to help to identify CQPs in milk and juices with bio-based packaging



Appendix E – Interview procedure

1. Say greetings to expert
2. Express appreciation to the expert for his/ her contribution in providing information
3. Ask for permission to record the interview
4. Give a short introduction
5. Explain the overview of the research including the aims of the interview
6. Explain the structure of the interview (consists of several parts)
   - General questions about the expert's background
   - Part A: The change of product packaging from conventional to bio-based materials
   - Part B: The insight about bio-based materials for milk/ juices packaging
   - Part C: The product quality with bio-based packaging
7. Tell the expert that the duration of the interview is more/ less 30-45 minutes
8. Ask the expert whether he/ she has a question, or everything is clear or not
9. The interview starts when the expert says he/ she is clear enough
10. Ask all questions based on the prepared questionnaire
11. Write the summary of his/ her answers and always confirm it at the end of the answers
12. When the interview finishes, show gratitude for his/ her cooperation

Appendix F – Timeline of the research

Time / Activities	2019																2020													
	Sep				Oct				Nov				Dec				Jan				Feb				Mar	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
Research proposal			*																											
Research method and design course (learning for the exam)																														
Developing a literature search strategy						*		*																						
Literature review										*																				
Applied food ethics course																														
Developing the 2nd research method												*				**														
Data collection														*																
Colloquia															18															
Data analysis																		*												
Writing chapter 4 (conclusions, limitations, recommendations)																				*		*		*						
Handing final thesis																														
Final presentation/ defense																														10

*meeting supervisor(s)
**holiday