Master Thesis

Concept Design of Fruit Preservation Product for Mozambican Smallholders

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Division of Machine Design • Department of Design Sciences

Faculty of Engineering LTH • Lund University • 2015

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Preface

This report finalizes our master thesis and thereby five years of studies at Lund University. We tried our best to make it as representative as possible.

First of all we would like to express our gratitude to the people in Mozambique for the warm hospitality and especially towards Lucas Tivana with family. Furthermore, thanks to Sandra, Graça and the interviewees for making our field studies both feasible and joyful.

We are also very grateful to ÅForsk for contributing with financial support, covering a great amount of the travel expenses.

Finally, we would like to thank the people involved in Sweden, Karl-Axel Andersson and Carl Lidgard for their guidance and Olaf Diegel for his perceptive supervision. Also, thanks to the people in the project team, Fredrik Malmberg and Randi Phinney.

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Christoffer Bratt & Gustav Ånger

Abstract

Being one of the poorest countries in the world in UN's Human Development Ranking, Mozambique struggles with both poverty and malnutrition. This runs counter to the fact that Mozambique is a country rich in natural resources with a great supply of crops. Research has shown that the lack of preserving methods within the agricultural field is a contributing factor that strongly affects the countries prospect of becoming more self-sufficient. In relation to this, researchers at Lund University at the Department of Food Technology have come up with a novel technique for drying fruit. The technique utilizes breathable fabrics (membrane textiles) and is referred to as *membrane assisted hygienic solar concentration*. The aim of this master thesis was to develop a fruit preservation product for the Mozambican smallholder farmer, making use of these membrane textiles.

In addition to initial technical objectives, field studies had to be conducted to discover user needs and fulfil a user centered design. The field studies were conducted in the rural areas outside of Maputo, Mozambique, and were mainly addressing the smallholder farmers. They included both observational studies and interviews with focus on present preservation techniques and methods.

All findings and insights from the research were interpreted into a product design specification, which worked as a comprehensible base for the concept generation. Using screening methods ten viable concepts were narrowed to three for refinement and selection.

The one selected concept is a bag designed in a circular shape with a zip sealing running the whole way around the circular cut. This enables the bag to have a varied size of the opening which facilitates the user during different operations. In case of production issues relating to costs a derivative to this concept was created. The derivative take use of the same working principle but is designed in the shape of a square and an isosceles with a straight zip seal.

Keywords:

User-centered design, Mozambique, Fruit preservation, Smallholder farmers, Product development, Concept generation

Sammanfattning

Denna rapport redogör för utvecklingsprocessen av en produkt för fruktkonservering ämnad att implementeras i Moçambique. Närmare bestämt har projektet sin bakgrund i pågående forskning som bedrivs av en grupp på Institutionen för Livsmedelsteknik på *Lunds Tekniska Högskola* (LTH), vilka i sin tur har ett samarbete med motsvarande på *Universidade Eduardo Mondlane* (UEM) i Maputo, Moçambique.

På UEM har man uppmärksammat den betydande mängd frukt som går förlorad efter skörd i Mocambique, vilken uppskattas vara 25-40% årligen. Förlusterna har delvis härletts till den brist på konserveringsmetoder som råder i landet. Medel för att tillvarata denna förlorade skörd kan komma att motverka undernäring och bidra till en potentiell inkomstkälla för de lokala bönderna.

Den ovan nämnda forskningsgruppen har upptäckt en ny metod för att torka frukt, i vilken fruktjuicer och -puréer innesluts i *andningsbara textilier*. Under torkningsprocessen pervaporeras vattnet i frukten till den omgivande luften under förutsättningen att luften inte är mättad på vattenånga. Flera användarsegment har identifierats, varav ett är de lokala bönderna i Moçambique.

Vid projektets start tillhandahölls en problemformulering som främst fokuserade på tekniska aspekter och funktionskrav. Häribland var ett av kraven att den inneslutna luften skall minimeras inför torkningen vilket också kom att få mycket fokus under den senare idégenereringen.

Utöver litteraturstudier, innefattande såväl tekniska- som användarstudier, utfördes fältstudier på landsbyggden utanför Maputo. Totalt, inkluderade fältstudierna sju halvstrukturerade intervjuer med tillhörande observationer, där ungefär en halv dag spenderades med varje intervjuobjekt. Löpande konversation med doktorander och professorer utgjorde även en väsentlig del. Fokus låg på att försöka utröna eventuella behov och se över vanor och beteenden beträffande de rådande fruktkonserveringsmetoderna och även andra områden som kunde komma att inverka på produkten. Exempelvis var det viktigt att ta reda på hur redskap och kläder rengörs för anpassning av befintliga metoder. Essentiellt var även att få en uppfattning om hur storskaligt jordbruket var. Utöver den generella uppfattningen om användaren var några viktiga resultat från fältstudierna följande:

- I dagsläget används väldigt enkla metoder för torkning av frukt där frukten sprids ut på plastväv för att ligga och torka i solen.
- Alla moment beträffande förberedning och tillredning sker med händerna och enkla redskap.
- Frukt odlas inte aktivt, snarare förlitar de sig på den obegränsade tillgången av vilda frukter.
- Intervjuobjekten hade alla tillgång till en lokal brunn.
- Rengöring av tvätt och disk skedde i mindre baljor.

Utifrån problemformuleringen, litteratur- och fältstudier upprättades en PDS (Product Design Specification). Häri ingick *persona*, *funktionsanalys* och begränsningar. PDS:en fungerade som underlag för merparten av idégenereringen som även fortlöpte under hela projektet. Idégenereringen fokuserade i det senare stadiet på att lösa de delproblem som ansågs mest kritiska. Som metoder användes bland andra *bodystorming, rapid prototyping* och snabba tester.

Idégenereringsfasen mynnade ut i en mängd skilda koncept där tio stycken valdes ut för *concept screening* varav tre togs vidare för *concept scoring*. Resultatet presenteras i form av ett koncept samt en alternativ lösning.

Huvudkonceptet är en variant på en påse som bygger på möjligheten att kunna öppnas upp helt för att förenkla tömmandet och blotta alla ytor för tvättning. Runt kanten på påsen löper en nyutvecklad typ av flexibel förslutning som möjliggör en varierbar öppning. Detta underlättar även för användaren i momentet att få ut luft.

Figure 1.1 Slutgiltigt koncept, stängd

Figure 1.2 Slutgiltigt koncept, öppen

Den alternativa lösningen bygger på en förenkling av huvudkonceptet. Eftersom förslutningen här är rak så behöver den bara vara flexibel i ett led vilket möjliggör en starkare förslutning. Nackdelen är att påsen inte kan öppnas upp helt utan istället måste vrängas för tömning och rengöring. Vrängningen underlättas av påsens utformning med sidorna vinklade.

Figure 1.3 Alternativt koncept, öppen

Figure 1.4 Alternativt koncept, stängd

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1 Introduction

This chapter will introduce the project, its background, scope, aims and delimitations. It will also present the structure of the thesis and explain the terminology used.

1.1 Background

The background for this master thesis project derives from previous and ongoing research conducted by a research team at the *Department of Food Technology, Engineering and Nutrition* at Lund University but is also closely linked to research done at the *Eduardo Mondlane University* in Maputo, Mozambique.

The research are rooted in the post-harvest losses in Mozambique, which is estimated to 25-40% each year [1]. These high rates covers all fruits and vegetables but is mainly due to fruits that are produced in large quantities and have a high spoilage rate, including both exotic and indigenous fruits. Mango, marula, mapf

, tangerine, massala and pineapple are fruits that have been raised as significant among these [2]. The losses are mainly due to an underdeveloped infrastructure in the region and lack of methods to preserve the fruit after harvest. This causes malnutrition and is a missed opportunity for an income.

A novel technique for fruit processing is now under development by the previous mentioned team at Lund University. In the process, a breathable fabric (membrane textile) is being used to concentrate fruit juices and purees through evaporation of water. This makes the outcome self-preservative and disposable for either later consumption or selling. The resulting preserve is very dependent on the chosen drying time and can be varied from a softer jelly-like product to a harder dried preserve.

The technology is referred to as *membrane assisted hygienic solar concentration* (MAHSC). It has great potential of being implemented within many market segments, and the smallholder farmers in Mozambique is forecasted as one.

There are numerous factors that speak in favor for this market segment. The warm and sunny Mozambican climate yields an increment in the drying rate, MAHSC does not require the same amount of external resources as many other large scale preservation technologies and furthermore, it is promoting food security to a greater extent than traditional sun drying.

This together makes MAHSC well suited for smallholder farmers in poor countries such as Mozambique.

The intentions for targeting the Mozambican market are to enhance food and economic security and improve life quality of those concerned. In the longer term, the team also have high hopes of introducing this concept in other developing countries on the African continent.

The technology has been proven to work and is a pending patent. What remains is a way to make use of the fabric, which will be the aim of this master thesis project.

1.2 Objectives and Delimitations

Until now, initial tests have been carried out on pouches consisting of two fused sheets, as yet, means no design has been established. This master thesis aim at making use of a breathable fabric and develop a conceptual design of a fruit preservation product for the Mozambican smallholder farmers. The product is to be used for concentration of juices/purees only, and cannot be utilized for storing and other subsequent operations. The main goal of the project lays within designing a user centered design solution applicable in this very context. Much focus will be on usability, regarding filling, emptying and cleaning. How these focus areas will be expressed in the final design may be affected by what the outcome is after the process, why a delimitation can be necessary. The size of the product will also play a crucial role for how these focus areas are treated. The only requirement concerning size is that the product should be easy to handle for one person, other than that this will be set corresponding to user needs.

In order to get the MAHSC-technology to work properly and optimize the drying time it is essential that enclosed air is minimized. Therefore it will also be of great importance to investigate how the air content can be reduced. Moreover, to secure a homogeneously dried preserve the maximum drying thickness cannot exceed 40 millimeters. Another area of interest is to make a sustainable solution, taking social and environmental impacts into account.

The final result of this master thesis project will be to produce a working concept and a physical prototype depending on time and means.

Concerning the material, it has yet not been decided upon completely. Wherefore recommendations of properties may be proposed in this thesis. However, this will not be focused on.

As result of findings and progression along the product development process, further delimitations may be set. These will then be clearly stated.

1.3 Structure of the Thesis

The thesis is constructed in the chronological order of the concept development process [3]. It starts with the research, literature- and field studies, followed by the conclusions that derived from that. This provided the groundwork for defining the user needs and product requirements in *Product Design Specifications*. This in turn became the basis for the *Concept Generation*, describing the process from ideation to a chosen concept. The result is presented as two concepts, described in two subsequent chapters. Finally the discussion sums up the authors' thoughts and reflections of the project.

1.4 Terminology and Nomenclature

To clarify what is what in the different states of the process of drying fruit, a simplification has been done for this thesis. *Fruit* is simply the untreated fruit as it comes from the tree. *Juice/puree* is the mashed prepared substance that is the ingoing product before it has been dried. *Preserve* is the end product that is the outcome of the preservation process. This could have any consistency from a syrup like fluid to a fruit leather.

MAHSC	Membrane Assisted Hygienic Solar Concentration

2 Methods

In this chapter the methods and methodologies used are extracted and described. From that methodology the project was divided into phases that also reappeared in the time plan.

2.1 Approach

As a foundation when approaching the project, the *Double Diamond Design Process Model* was used [3]. The method was chosen since it leaves room for creative thinking and was familiar to the authors of the thesis.

2.1.1 Discover

The first phase of the project is of exploratory nature. This initializes the project and the main idea is to gather inspiration and conduct research to get ideas and a feel for the project and its subjects. This research can be done with both qualitative and quantitative methods [4, p. 8].

A central and vital part of the discovering phase was the field research in the rural areas surrounding the Maputo, Mozambique.

2.1.1.1 Literature Studies

To grasp the many subjects of the thesis project, literature regarding the different subjects are perused. Most importantly, reports and articles regarding the project are delved into. This is being done to get a deeper understanding and elucidate possible needs and constraints.

2.1.1.2 Field Studies

The main idea with field studies is to meet and observe users in a real user setting, in which they work or live in. Field studies are particularly useful at an early stage of the design process when uncertainty regarding user needs most likely is high. Field studies consist of collecting data through observations, interviews and/or apprenticeship. The aim with the field research is to learn about needs, limitations and user environment [5, pp. 49-50].

IDEO's Human Centered Design Toolkit [6] served as guide for individual interviews and observational studies.

2.1.2 Define

This phase takes off from the gathered information and insights from the *discover* phase. This is narrowed down, interpreted and structured to get a clear definition and alignment of the project [4, p. 8].

2.1.2.1 User Persona

A *User Persona* embodies and brings together the user research by having one persona representing a group of users. A persona is normally visualized through text and pictures. The main purpose with the persona is to ensure that focus is maintained throughout the design process on delivering value to the intended users [4, p. 16].

2.1.2.2 Functional Analysis

The basic idea with the functional analysis is to focus on defining the underlying function and not complete solutions. This helps to avoid conventional solutions and broadens the approach. The gist of the procedure is to formulate all functions with a verb and a noun and then set the main function and classify the rest as necessary or desirable [6, pp. 34-41].

2.1.3 Develop

The core of this phase is to generate ideas and concepts based on the specifications from the define phase. The concepts are then prototyped, tested and evaluated iteratively [4, pp. 7-9].

In this phase, the evaluation is based on the methods described by Ulrich and Eppinger.

2.1.3.1 Concept Generation

Brainstorming is used to generate as many ideas or solutions to a given task as possible. They are useful to break out of thinking patterns and develop completely new ideas. Furthermore, key ideas are identified to develop further [7, p. 17].

Negative brainstorming and *how would x do it?* are two different methods of brainstorming. *Negative brainstorming* aim at generating ideas that are considered the worst ones, in order to trigger the better ones. With *how would x do it?* the participants try to generate ideas from the perspective of different personas or professions.

Bodystorming applies to the same rules as brainstorming and also aims at generating ideas. The difference with *bodystorming* is that it involves the body explicitly, by interacting with physical objects and simulating physical actions [5, p. 45].

2.1.3.2 Concept Screening and Scoring

The purpose with Concept screening is to evaluate concepts quickly and narrow the number of concepts for further improvement. The different concepts are compared in a selection matrix and scored in relation to a reference concept.

Concepts scoring is used after concept screening for the remaining, improved, concepts. It also utilizes a selection matrix, but as opposed to concept screening, weights the

relative importance of the criteria. This provide a higher resolution in the comparison. The concept with the best score qualifies for development [8, pp. 149-158].

2.1.4 Deliver

The last phase of the project takes the final concept through extended tests, finalizes the design and signs off the project [4, p. 9].

2.2 Time Plan

The project was divided into four phases according to the *double diamond design process*. The phases *discover*, *define*, *develop* and *deliver* each ended with a milestone, synthesizing the phase and provides an outset for the next.

In order to get contacts for, plan and not at least finance the field studies, a substantial amount of time were reserved for this.

As a part of the examination, a public review of another master thesis is mandatory, wherefore this also is included in the time plan.

The time plan can be seen in Appendix C.

2.3 Funding

Financial support to cover the costs for the field studies were applied for and granted by *Stiftelsen ÅForsk* to a sum of 20 000 SEK.

3 Technical Research

In this chapter, an extract of the conducted technical research is displayed, with literature research mainly serving as basis. The aim was to get a deeper understanding, get inspired and mostly explore design opportunities. The chapter presents the underlying technology, permeation, material research and fruit preservation.

3.1 The Technology

The technique that this project derives from is termed *membrane assisted hygienic solar concentration* (MAHSC) [9]. This technique utilizes a breathable fabric to concentrate fruit juices and purees.

The breathable fabric has one inner membrane that serves as the active layer, and one outer layer to withstand abrasion. The inner layer is permeable to water vapor but not liquid water, thus allowing only individual water vapor molecules to pass through. By encapsulating fruit juices or purees in the fabric, water is evaporated into the void volume of the fabric and left to the surrounding through diffusion.

The transport of water molecules are driven by the difference in partial pressure of water in the fruit substance and the relative humidity of ambient air. Diffusion of water molecules will occur as long as the relative humidity in the ambient air is unsaturated, drying the fruit substances as a result. The drying rate can be increased by heating either the surrounding air and/or the fruit substance since this creates a larger difference in partial pressure.

What end-product the MAHSC process results in is highly dependent on both raw material and drying time. Either a leather-like product or a concentrate similar to syrups/jellies can be produced.

The MAHSC technology has been proven to work and there is a patent pending at the time of writing [10].

3.2 Permeation

Permeation is the process during which molecules passes through a solid material or membrane, in this case a breathable fabric, from an area of higher concentration to an with lower. The movement of molecules requires a thermodynamic driving force, which for gases and solvents is the gradient in chemical potential related to the concentration of migrating molecules.

The flow (or flux) through the membrane is except the driving force also affected by a resistance to the passage of the molecules. This material resistance is caused by factors that emerges during different stages of the permeation. Firstly during the absorption of the molecules into the material, secondly during the diffusion within the material and thirdly when the molecules are leaving through desorption. The process is shown in Figure 3.1 where *L* represents the thickness of the material.

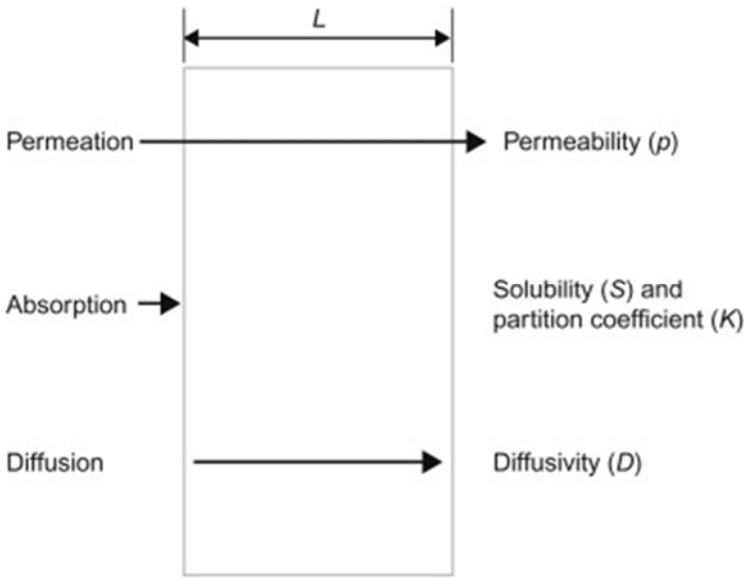

Figure 3.1 Permeation process [11, p. 38]

The absorption and desorption respectively is a measure of the affinity of the substance for two mediums with which the substance is in contact with. For gases, the affinity can be expressed with solubility. The solubility normally has a linear relationship to the partial pressure of the gas, for which Henry's law can be applied:

$$p = \sigma \cdot x_s$$

Where p are the partial pressure for the gas in the atmosphere, x_s the molar fraction of the gas in the material and σ is the Henry's law constant in Pa.

The diffusion on the other hand obeys Fick's second law:

$$Flux, J_d = \frac{Q}{A \cdot t} = D\frac{(C_{s1} - C_{s0})}{L} \Rightarrow \frac{Q}{t} = A \cdot \frac{(C_{s1} - C_{s0}) \cdot D}{L}$$

Where Q is the amount of diffused moving substance (mol), A the cross-sectional area, t time (second), $C_{s1} - C_{s0}$ the concentration difference, D diffusivity and L the thickness of the material.

Through the relation, it can be obtained that the diffusion rate is directly proportional to the difference in concentration of the molecules within the material [11, pp. 37-49].

Furthermore, the rate is inversely related to the thickness of the material. Hence, a thinner fabric speeds up the process. Fick's laws also show that the rate (mol/second) of particles moving is increased with increased membrane area. If one instead observe the complete volume of the product enclosing the fruit juices/purees, a larger surface area compared to volume is preferable.

3.3 Manufacturing of Breathable Fabrics

Coating and laminating are the two main manufacturing methods for combining two or more materials to form a multilayer textile. Typically this means a fabric together with a polymer or another fabric.

Coating can be defined as applying one or several layers of material, usually in viscous form, directly to the fabric. Laminating on the other hand, is a method where pre-extruded films or other fabrics are bonded to the primary substrate.

Both coating and laminating include a great variety of different processes and machines. What process to use depends on the substrates characteristics, different materials requires different techniques. Generally for laminating and coating processes, the substrate comes in the form of a long sheet and is fed through rolls or accumulators. In order to keep the process uninterrupted and cost efficient, the length of the fabric should be as long as possible [12, pp. 10-41].

3.4 Designing with Fabrics

As mentioned, multilayer textiles in general come as flat sheets on rolls. However, technologies for producing 3-dimensional seamless waterproof fabrics also exist [13, p. 24]. If utilizing fabric rolls with flat sheets, many different methods for joining pieces together exist.

Welding is maybe the most common method to use when designing in waterproof fabrics. Welding include a variety of processes which fundamentally all are different hot-melt process. These include ultrasonic welding, high-frequency welding and radio-frequency welding [7, p. 96].

Thermoplastic materials such as PVC coated and laminated polyesters are the materials that is most suitable for welding. Nonetheless, materials that are not thermoplastics can be used for welding applications. For these materials an adhesive tape must be used to complete a weld though. Compared to regular seams, welded seams have the advantage of being more long lasting in the field. The disadvantage of using welds is primarily the fact that they are more expensive than regular seams for many applications [14]. What makes it a bit problematic of using sewed seams for waterproof applications is that the sewing holes causes the water to seep through. This problematic can be treated by processing the seams with a water-repellent finish but this only slows down the seepage rather than protecting fully [13, p. 24].

3.5 Fruit Preservation

Preservation of fruits can be obtained in various ways, one of which is drying or more precise, dehydration. The dehydration process prolongs the storage life by changing a

product's available water content, meaning water that is not bound by molecules in the fruit and is vital for bacteria, yeasts and microorganisms in order to grow. Furthermore, the available water can move freely and line up at the surface in a state of equilibrium with the surrounding air. This is utilized to measure water activity, which gives a direct answer to a product's amount of available water [15, p. 46].

The water activity, measures the ratio of the vapor pressure of water above the food (p) compared to that of pure water (p_0) at the same temperature:

$$a_{w=\frac{p}{p_0}}$$

Hence, lowering the water activity will preserve food against microbiological and chemical deterioration. Exactly what water activity that is required depends on the particular foods and microorganisms but in general a water activity below 0.7-0.8 is necessary. The water activity furthermore strongly relates to the food properties. Food with low water activity, low moisture foods, generally is harder and more inflexible.

Another vital aspect of the water activity concerning food stability is that it affects the deteriorative reactions of foods. This involve enzymatic browning, flavor deterioration and breakdown of structural polysaccharides which all proceed more slowly at a low water activity [16, pp. 317-329].

4 User Research

This chapter starts with literature research covering subjects such as malnutrition and agriculture but then focus on the field studies conducted in Mozambique. The aim of these studies was like the previous chapter to get a deeper understanding of the user and the surrounding context, get inspired and explore design opportunities.

4.1 Agriculture in Mozambique

Mozambique is a country in Southeast Africa with the size of 802 000 km^2 (almost the size of Scandinavia) and a population of 25.1 million[1]. The climate is tropical to subtropical with an annual precipitation of 750 millimeters in the south to 2000 millimeters in the north which primarily falls during the wet season from November to April. The country is afflicted by both tropical storms, that causes intense rainfalls and flooding during wet season, also severe droughts that occurs during dry season [17].

Being one of the poorest countries in the world and positioned at 178[2] in UN's Human Development Ranking 2014 [18], Mozambique struggles with both poverty and malnutrition even though the country have a rich supply of crops and natural resources.

46% of the children of Mozambique under the age of five suffer from stunting (chronic malnutrition), 6% are wasted (acute malnutrition) of which a third of these severely and 15% are underweight [19, pp. 82-83]. The malnutrition affects the children in many different aspects from physical health to underdevelopment and can have irreversible consequences. The hunger season starts when the last season's harvest is low, usually around December, and spans until the next harvest is ready around March [20, pp. 113-120].

Agriculture is Mozambique's most important sector in terms of occupation and employs 81% of the economically active population [21] but because of civil war and drought the production has great fluctuations. The country is not self-sufficient with food partly due to an underdeveloped infrastructure and lack of preserving methods.

One sector that possesses great potential is the domestic fruit sector, however smallholder farmers lack access to inputs and improved farming practices. This causes low productivity and high post-harvest losses, which is estimated to be 25-40% [1, p. 21]. These high rates mainly derives from fruits that are produced in large quantities and have a high spoilage rate, including both exotic and indigenous fruits. Mango,

[1] 2014
[2] Out of 187

marula, mapfilwa, tangerine, massala and pineapple are fruits that have been raised as significant among these [2].

4.2 Field Studies

As part of the *discover* phase, field studies were conducted with the purpose to supplement the initial literature research with qualitative data. Qualitative research is appropriate in the early stages of the design process and can help developers question assumptions and uncover hidden needs and aspirations [22]. The field trip was taking place from March 1 to March 18th in Maputo, Mozambique.

4.2.1 Approach

To increase the level of research and to be able to do relevant research, field studies in Mozambique needed to be conducted. The field studies were mainly addressing the smallholder farmers, the end users of the product. The field studies were planned to include both in-context interviews and observational studies in order to get an overall view, thus ensuring that verbal answers corresponds to actual behavior.

Before the field research, very little was known about the smallholder farmers, their needs and how a potential product could create value for them. Therefore the main goal was to gain a greater understanding of the end user and the context in which the product ultimately will be implemented in. The approach was to find out as much as possible about how things are handled that could potentially relate to the product. This, since it was assumed that habitual behavior patterns are hard to displace and that the product rather should be coherent with these.

Ultimately the field studies would result in a list of insights and gatherings that could reveal different user needs connected to the product.

4.2.2 Preparation

The observations and interviews are somewhat hard to distinguish from each other execution-wise and were thought of as interrelated already in the preparations. Both observations and answers during interviews could give clarity to the questions that had arisen in the pre-study phase. Therefore, questions requesting both verbal answers and physical actions were formulated. A sheet with a total of 52 specific questions was created to work as a foundation. These questions acted as example questions and were modified depending on interviewee and how each interview turned out.

The preparations were performed in the following order: First, significant topical areas were brainstormed. The main topics were then expanded to subcategories and questions formulated that responds to these subcategories. Having phrased the questions, the logical flow in which they should be asked was decided. This division derived from three categories, referred to in *The Human Centered Design Toolkit* as open specific, go broad and probe deep [22]. Finally the internal order within these categories was established based on the importance of the questions.

4.2.3 Execution

The field studies emanated from Eduardo Mondlane University, Maputo, Mozambique and were executed in different rural areas outside of Maputo. A total of seven formal interviews were conducted: five semi-structured interviews with smallholder farmers and two open interviews; one with a former foreman at a fruit processing industry and one with a business leader at a company specialized at various fruit processing techniques. All interviews were carried out with an interpreter with knowledge in the field and a somewhat personal connection to some of the interviewees.

The interviews took place in the interviewees working environment, equivalent with the home environment for the smallholder farmers. Observational studies were conducted in connection with all the interviews. One of the co-authors was assigned to lead the interviews as well as taking photos and the other to take notes and document observations. Approximately half a day were spent with each interviewee for both observations and interviews.

As stated, different topics for observations had already been planned for prior to the field studies, see Appendix A. Furthermore, a substantial number of observations were done in addition to these. Some areas observed were for instance the preparation of different fruits, washing of clothes and sales of fruit at the informal market. Furthermore an inventory of available tools and other equipment was made.

In addition to the mentioned interviews and observations, numerous conversations and informal interviews took place with researchers at the university.

4.2.4 Limitations

The interviews and observational studies were strictly held in the rural areas outside of Maputo, why the findings just give indications for this geographical area. Furthermore the sample is not big enough to determine any average behavior. It should therefore not be considered as statistical data but rather serve as an indicator and unveil issues and needs related to the product.

The selection of participants were mainly restricted to villages that had some sort of connection to researchers at the Eduardo Mondlane University. Hence, the interviewees might not have been representative for the whole spectrum of users.

Since all interviews were done with an interpreter, information may have got lost along the way. Also, it is possible that the interviewees acted differently from what would have been the case in use of direct communication.

4.3 Findings

The raw data collected during the field studies were refined into a comprehensible list of insights with as little interpretation as possible.

4.3.1 Farmers

Amongst all the interviewed farmers it existed several common denominators. What became obvious early on was the fact that it is almost exclusively women working with

agricultural activities. Even though the age of the farmers varied widely, only women were observed in the fields and at the informal markets where the fruit were being sold.

All the interviewed farmers had a small piece of land; living and growing crops on the same. No fruit trees were planted actively, instead they relied on wild fruits in the surrounding forests, which they had within walking distance.

The houses where they lived were very primitive, most often built in a hut-style with corrugated sheet as roof. Simple stone houses were also common. They lacked electricity but several of the interviewees owned a mobile phone which they could charge at nearby facilities. Furthermore, a majority of the interviewees expressed a concern of being socially and economically vulnerable but none had ever been in contact with, or had any experience of charity organizations. All the villages visited had a local chief, advising the farmers and working in contact with the government.

Figure 4.1 Typical house

4.3.2 Fruits of Mozambique

Mozambique possesses a wide range of different fruits and varieties of these and the edible fruit trees constitutes a substantial part of the Mozambican woodlands. The most significant fruits that were ripe and harvested during the field studies were marula, mapfilwa, massala and muquaqua. As most of the fruits are indigenous and lacks common names in English, they will be referred to their names in Portuguese.

4.3.2.1 Marula

Sclerocarya Birrea, is an indigenous fruit that is bound by many traditions. The fruit is often fermented to make *okani*, a liquor for festivities only and that must not be sold. If this tree grows on one's land, the landowner is responsible for the production of this liquor for the community and are not allowed to take down the tree without permission from the local chief. The fruit is also used to produce jelly but has problems with worms. This makes large quantities for commercial production problematic but is not a problem for smallholders.

4.3.2.2 Mapfilwa

Figure 4.2 Mapfilwa on sheets of woven plastic

Vangueria infausta, is an indigenous fruit that is commonly used in times of food scarcity. In some areas, this is the only ripe fruit in the time between March and July. The fruit is traditionally used to make jam, juice and, most importantly, porridge which serves as an important source of nutrition for the children.

It is occasionally sundried, simply by spreading the fruit on sheets of woven plastic. When dried, the fruit can beneficially be rehydrated at a later occasion without notable losses.

There are many variations to the species and for commercial purposes it is wanted to have a sweeter variety for juices and a bitterer one for liquors.

The fruit tree is somewhat encumbranced with superstitions and is believed to bring bad luck when having it on the farmland.

4.3.2.3 Massala

Strychnos spinosa, is an indigenous fruit that is used to make jam. The fruit has a lot of seeds in proportion to pulp and is difficult to remove if used in a bigger scale. The fruit is traditionally not dried because it easily becomes bad and starts to ferment.

4.3.2.4 Muquaqua

Figure 4.3 Pestled muquaqua flour

Strychnos madagascariensis, is an indigenous fruit that is commonly dried. The fruit pulp is dried in the sun and is then pestled for a flour, alternatively smoked before being pestled to get an oily paste. These preserves provides a high satiation and a single spoonful can be enough to last for hours and is consequently commonly used in times of scarcity. They are also the fruit product that is most profitable for the interviewees.

4.3.3 General Findings

The methods that the interviewed smallholders used for fruit processing and preservation had been the same for generations and were strikingly simple.

In order to dry fruits, all the interviewees used the same method of sun drying. The fruit were simply spread on woven plastic sheets that they had put on the ground. Depending on which fruit that were dried, the time to achieve a desired result was changed accordingly. For some fruits the drying was preceded by some sort of preparation, such as removal of seeds and slicing. During the interviews, it transpired that the number of different fruits that were being dried was notably low. Asking why, the respondents did

not really have a clear answer, but when asking about particular fruits it became clear that the mentioned method was not appropriate for all fruits.

A question was raised if they had any problems with pests of any kind, particularly concerning the fruit that were being dried. One of the interviewees said that she had some problems with goats grazing on her property and therefore dried the fruit on the roof. Otherwise none of the interviewees expressed any concern about this matter.

Furthermore, the interviewees did not have any experience of more advanced drying processes. This might indicate that they are very bound by tradition. Nevertheless, there were no signs of hostility towards modern equipment, since mobile phones were very common and one person even had solar cells to charge it.

The supply of tools and kitchen utensils were very limited for all the interviewees. They had basic cookware, such as pots, ladles and bowls. Except from this equipment, they lack more advanced tools and every operation in the fruit processing was done by hand; crushing the fruits to a puree for instance. Neither did they have any precise measuring tools. It was noted during the observations that all form of preparations and other tasks connected to cooking and fruit processing were performed directly on the ground. This was being done either in a sitting position or standing up.

Figure 4.4 Preparation of fruit porridge by hand

Concerning sanitation and keeping clothes and utensils clean, all interviewees used the same means. Both cleaning and washing were done in small plastic tubs filled with water and detergents. They all got their water from a village well and claimed that there never were any problems with the water supply. The distance to the well varied a lot

for each case, from just a few minutes to half an hour. This affected how often they went to the well which in turn affected washing- and cleaning habits. Even though all the interviewees used water from the well for cleaning and washing, people washing in rivers were observed.

Repeatedly throughout the interviews it emerged how important the fruits are to both serve as a source of income and a source of nutrition to themselves. Even though none of the interviewees planted fruit trees actively they emphasized that the amount of fruits were limitless during harvest season. What sets the boundaries are the seasons for ripe and the amount they could carry.

The area of application seemed to vary for each and every fruit. Fruits were eaten fresh, made to liquor, jam, porridge, paste and flour. The products were made according to tradition. It was pointed out that some farmers are superstitious about how some fruits must be treated. However, this was not of any concern for the interviewed farmers.

The fruits that were being sold at the informal markets were almost exclusively fresh. This was both observed and confirmed during the interviews. The exceptions were the dried fruits that had been further processed to a flour or paste. These products are eaten during drought when the fruit supplies are low, and it was stated that they function as means for survival. They were, according to the interviewees, also the most beneficial to sell in terms of price. This indicates that processing of fruit can increase the value. When asked about which fruits they would like to process and dry to a greater extent if possible, no direct unanimous answers were received.

The processed fruits were often stored in big buckets and sold in small plastic bags. What was observed during the field studies was that a substantial amount of time and effort are necessary to process the fruits to finished products. It also emerged from one of the interviewees that some products had to be neglected since they were too time consuming.

5 Product Design Specification

This chapter defines the design specifications that needs to be taken into consideration. It also presents a User Persona and a functional analysis. The aim is to interpret the research to be a comprehensible base for the concept generation.

5.1 Initial requirements

Before the project started, an initial brief with product requirements/constraints was received from the project team. The list with constraints is seen below.

- The device/product is designed for pourable/liquid-like fruit products (either a juice or puree).
- The maximum drying thickness is 4 centimeter (to secure a homogenous drying).
- The product is horizontally oriented during drying (to secure a homogenous drying).
- The product is inexpensive.
- The product is easy to handle for one person.
- The product is reusable.
- A safe preserve is facilitated (in a microbiologic point of view)

5.2 User Persona

To visualize the potential user, a *User Persona* was created. The persona was based on the user research and embodies the target group.

5.2.1 Profile

Martha, age 25, lives with her four kids aged 2, 3, 6 and 8. The oldest two go to public school. Married but the husband works in the city and is often absent.

5.2.1.1 Living situation

Lives in the rural areas in Maputo district of Mozambique. Her house is very simple with only room for a bed and some basic stuff. She lacks electricity but owns a mobile phone that she charges at the local shop.

5.2.1.2 Education

Analphabetic, no formal education. Her mother tongue is Ronga but she speaks Portuguese for the sake of her children.

5.2.1.3 Income

She makes a living from farming activities, including growing crops on their small piece of land and collecting fruits from the surrounding forest. She does as much of her labor as possible in the shelter of the shadow under a cashew tree. Twice a week, she goes to the informal market to sell her weekly harvest. This gives her money to buy sugar and other necessities.

Her favorite time of year is around Christmas, then the access to fruit is unlimited and her income the greatest. During dry season the fruit supply is poor and the vangueria infausta fruit serves as an important nutrition source for her children.

Now and then she has some money left to proceed with her new house, which has been under construction for four years and is taking form next to the existing one.

5.2.1.4 Daily habits

Her day starts at 4 am and she is usually asleep by 6 pm. Goes to church every Friday and Sunday.

5.2.1.5 Needs

She and her family is in need of an increased income. For the moment their economy is very fragile and does not leave room for any unexpected expenses. For instance her pestle just broke and she cannot afford a new one for the moment.

5.2.1.6 Aspirations

Her highest hopes are to someday own a car and have electricity installed in their house.

5.3 Underlying Needs and Requirements

A function analysis was done to serve as a basis during the concept development process. It ensures that no crucial aspects are overseen and helps to evaluate the different prototypes. The way of compiling the function analysis was based on *Vilda Idéer och Djuplodande Analys* written by Jan Landqvist [6].

All insights obtained during observations, interviews and literature studies led up to a list of needs and wants for the product.

5.3.1 Function Analysis

The function analysis is divided into the subcategories *use*, *design*, *production* and *end product*. A *main function* (MF) is chosen and the others are classified as, *needed* (N) or *desired* (D) functions.

5.3.1.1 Use

The use category concerns every need related to purpose of the product and demands that is put on the product.

Table 5.1 Function Analysis, Use

Function		**Class**	**Notes**
concentrate	fruit purees/juices	MF	
enable	preservation	N	
ease	filling	N	
ease	wash	N	
be	safe	N	
allow	lift	N	
ease	emptying	N	in various containers
allow	drying	N	after cleaning
be	manageable	N	by one person
encourage	reusability	N	
work	autonomously	N	
minimize	enclosed air	N	
be	intuitive	D	
ease	carrying	D	
allow	hanging	D	
express	fruit compatibility	D	
ease	opening	D	
minimize	time	D	of use
be	aesthetic	D	
minimize	spill	D	

appeal	women	D	
allow	traditional carrying	D	
minimize	risk of misuse	D	

5.3.1.2 Design

The design category state technical criteria that the product need to fulfill.

Table 5.2 Function Analysis, Design

Function		**Class**	**Notes**
withstand	sunlight	N	
allow	draft	N	
be	reusable	N	
prevent	pests	N	
give	uniform drying	N	
endure	detergent use	N	when cleaned
indicate	end of process	N	
minimize	drying time	N	
minimize	enclosed air	N	
minimize	maintenance	N	
ease	logistics	N	
minimize	environmental impact	N	
enable	tight sealing	N	
withstand	wind	D	
ease	mounting	D	
allow	pesticides	D	
minimize	weight	D	

minimize	material use	D	
resist	smoke	D	
withstand	rain	D	
withstand	weather	D	
maximize	surface area	D	
allow	stacking	D	
be	compatible	D	with solar dryer

5.3.1.3 Production

Production involves criteria that affect manufacturing.

Table 5.3 Function Analysis, Production

Function		**Class**	**Notes**
be	cheap	N	to produce
manufacturable	locally	D	

5.3.1.4 Preserve

Involves needs that might relate to the products ability of producing a desired preserve.

Table 5.4 Function Analysis, Preserve

Function		**Class**	**Notes**
add	value	N	
keep	nutrition	N	
look	appealing	D	texture

5.4 Defining Delimitations

Part from the functional analysis, some areas of focus needed to be defined closer as well as constrained. This regarded the *fruit and preserve*, *shape and size*, *removable parts*, *fabric*, *cognitive ergonomics*, *production* and *other delimitations*.

5.4.1 Fruit and Preserve

As it is desired to preserve a wide range of fruits, and as different fruits are suited for different preserves, for the final preserve, the product should be able to handle as wide a range of fruits and preserve types as possible. The starting fruit is mashed into something between a juice and a puree with an eventual additions such as sugar is added.

The final preserves could be anything from fluid to something leather like. However, the more dried the preserve gets, the more it will differ from the starting juice/puree. This could therefore compromise the optimization for the use of the more commonly desired preserve.

5.4.2 Shape and Size

One of the factors that affect the manageability the most is the size. From the field research it was found that the target group is dealing with products of sizes over 20 liters on a daily basis but since most of their common tools only handled sizes less than 10 liters this will be the limitation.

The product might be used for a varied volume of fruit and should be designed to manage small batches. Comparing a large product with a number of smaller products with the equal combined volume the larger could have some potential benefits. It could be seen as more efficient and therefore reducing the risk for user errors. When using less material in relations to fruit the product could have a lower production cost. Less corners and edges will make the product easier to clean and will therefore be more hygienic. This could also affect uniformity of the drying to the better. Furthermore, a large product could increase the *affordance* [23, pp. 9-11] as it have less of the appearance of a package. This expresses reutilization.

By limiting the maximum volume and making the product smaller it becomes more manageable. This eases the handling when cleaning and minimizes the risk of misses for the benefit of hygiene.

On the matter of production, the size and shape will affect the utilization of the fabric. This might be an issue that should be consulted with the developer and the manufacturer for an optimization regarding economic and environmental aspects.

To conclude, the product should be able to handle any volume between its minimum- and maximum value of which the minimum should be close to zero and the maximum should not exceed 10 liters. The thickness should be as consistent as possible with a maximum thickness of 40 millimeters.

5.4.3 Removable Parts

Since the product concept is not yet developed, the issues whether to have removable parts or not is hypothetical and a possible solution could just as well be a combination of these or in other ways circumvent the problems.

Having removable parts opens up for separating these which then could make the handling when cleaning the product more manageable. Removable parts will also be

more convenient for replacement or reutilization when a part is worn out or breaks. This will potentially make the product cheaper for the user and more environmental friendly. On the other hand, these loose parts could more easily be lost and consequently make the product unusable and have a reversed effect on price and environment.

The possibilities to optimize the product for different positions is widened by the opportunity of removable parts, especially if it is made rigid. It does, however, add complexity to the handling of the product in terms of adding steps and might also need a sleight of hand. This places high demands on the product in terms of affordability and could increase the misuse and more easily damage it. Open parts could easily collect dirt and aggravate the assembly. This could also lead to an increased wear of the product.

5.4.4 Fabric

The delimitations concerning the fabric in relation to thickness are somewhat unclear but there are some indications that a thicker fabric could affect drying rate.

Regarding the color there is no restrictions within reasonable limits. However, some of the tests that were done, indicates that a dark color could raise the temperature to an unwanted level. Furthermore, some bright colors could have the benefit of transparency. This could play an important role in terms of *feedback* when handling and especially during the removal of air.

Furthermore, the fabric used in the design will be considered to be manufactured as plane sheets on rolls due to the lack of information regarding the possibilities of producing 3-dimensional geometries.

5.4.5 Cognitive Ergonomics

The user interaction is of most importance to minimize incorrect handling and to raise the efficiency. In general, the product should avoid complexity and should be able to manage a blunt handling and a rough environment.

Since the product is novel, it is even more important to aim for an as high *affordance* as possible [23, pp. 9-11]. For the cultural differences, shortage of education and for the wide range of languages spoken there should be little or no text on the product. Pictures and other symbolic indications should also be well-reasoned. This places high demands on the formation of eventual instructions. If something is needed to be explained, there should be enough room for the explanation on the product.

Another decisive factor is *feedback* [23, pp. 27-28]. If the concept is based on knowing the filling level or any other critical point, the user must get the feedback needed to obtain this. This also concerns the awareness of the drying process.

5.4.6 Production

For everything that relates to the production, the aim is somewhat arguable. A general point of view is to do this as affordable as possible but the nature of the project adds

concerns that might conflict with this. For instance, it is desired to have the production locally but this could be argued in terms of quality, economic, environmental and other ethical factors along with creating jobs locally. This is closely linked to the main goal with the overall project. The product must either way not solve a problem by adding another.

5.4.7 Other Delimitations

During the technical research it was found that the dehydration rate is increased if the freely exposed membrane area is maximized. This encourages a design where the product is lifted from the ground. However, since no information regarding the rate of which the fruit juice/puree must dry to promote a safe preserve or other information regarding this matter was obtained, this was not taken into consideration.

A great insight from the user research was that the means and method used by the smallholder farmers for fruit preservation are all very simple. It was believed from the authors that this must be reflected in the product design, thus not adding any unnecessary parts.

6 Concept Generation

This chapter will cover the concept generation, from the ideation through methods of screening to a selected concept. The aim is to go broad to get a wide range of different concepts to evaluate and, as objective as possible, find the overall best solution.

6.1 Ideation

Ideation sessions has played a crucial role as part of the project in order to generate ideas. These sessions started early on, already before the product specifications had been set, following the motto: the more ideas the merrier.

Except from generating ideas solely within the group, a brainstorming workshop was also conducted including five participants. All these participants were in the same field of knowledge, having a mechanical engineering background. The methods used were *think out loud*, *negative brainstorming*, *how would x do it?* and *association*.

At an early stage, ideas were generated without the concern of having to fulfill a certain task or product function. Later on in the process, and during the workshop, a more structured method was applied where the ideation was divided into a number of sessions covering critical sub problems one at a time. This decomposition was inspired from *A Five Step Method* described by Ulrich and Eppinger [8, pp. 121-123]. The sub problems that systematically were worked through were the following:

Filling - how the product can be easily filled with fruit

- emptying - how the preserve can be easily removed from the product
- washing - how the product should be designed to be kept hygienic
- sealing - what sealing methods can be applied
- air removal - the air should be removed from the fruit somehow before the drying process starts
- uniform drying - how the design could maintain a homogenous drying.

Brainstorming took place around each and one of these sub problems and general ideas for how they could be solved were often thought of. These ideas then worked as topics for further brainstorming. For example, the concern of uniform drying led up to ideas such as controlling the volume with fixtures and reducing the cross-sectional height once filled.

Worth mentioning is that many of the subcategories are intertwined affecting one another. Therefore, a solution to one problem in many cases also solved another, or hindered the possibility to do so.

6.2 Concurrent Processes

Throughout the process, some parallel processes were running concurrently. These included different kinds of rapid prototyping from sewing and paper folding to wooden constructions and 3D printed parts. These were tested and evaluated along with scenario based *bodystorming* and experiments using fluids simulating juices and purees among other things. These processes were evolving from quick and dirty to become more sophisticated the further ahead the process progressed.

6.3 Generated Concepts

From a substantial amount of ideas, concepts were formed, structured, combined and culled into ten viable concepts. The different concepts had focus on different sub problems. Many dealt with the problems regarding air entrapment and the difficulties of handling when filling, emptying and washing. Another recurring problem was the overloading and thereby the volume change that was needed.

Some of the shared detail problems like making corners rounded was not taken into account at this stage.

6.3.1 Concept A

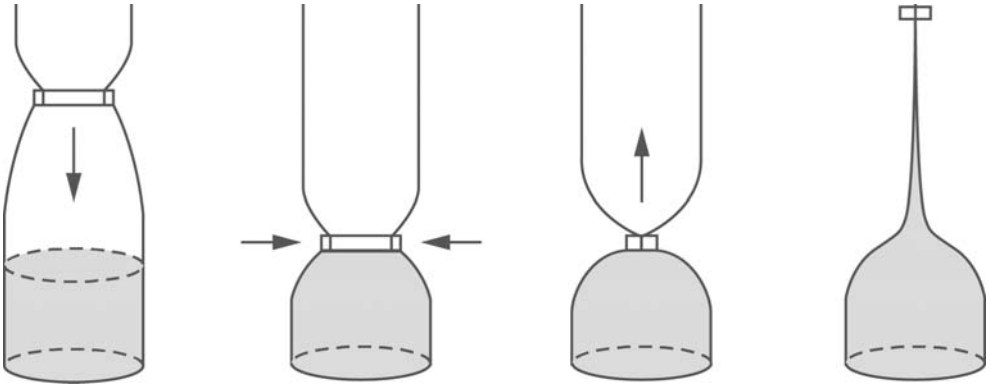

Figure 6.1 Concept A

The concept is based on a pouch solution with the attribute of separating the air from the juice/puree by squeezing the bag with a removable device. After the pouch has been filled, the device is slipped over from the top, towards the surface of the juice/puree. Aligning the surface, the hollow section of the device is decreased to clamp the fabric together and cut the surface. Sliding it up the air is removed and when it reaches the top it closes the pouch. This will make the bag variable and solves the problem with volume change.

6.3.2 Concept B

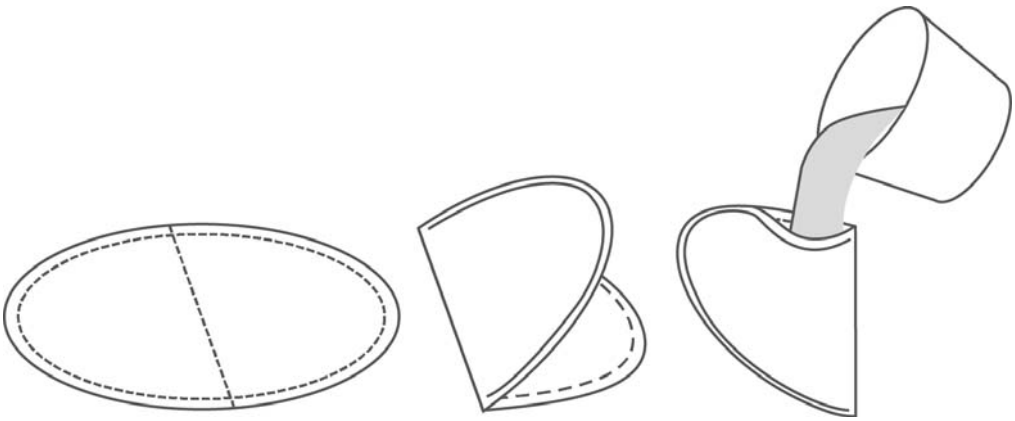

Figure 6.2 Concept B

By having a zipper-like sealing running the whole way around the circular cut, the concept could have varied size of the opening; from wide to a narrow opening for releasing the entrapped air. Being able to fully open up the product eases the emptying and cleaning.

6.3.3 Concept C

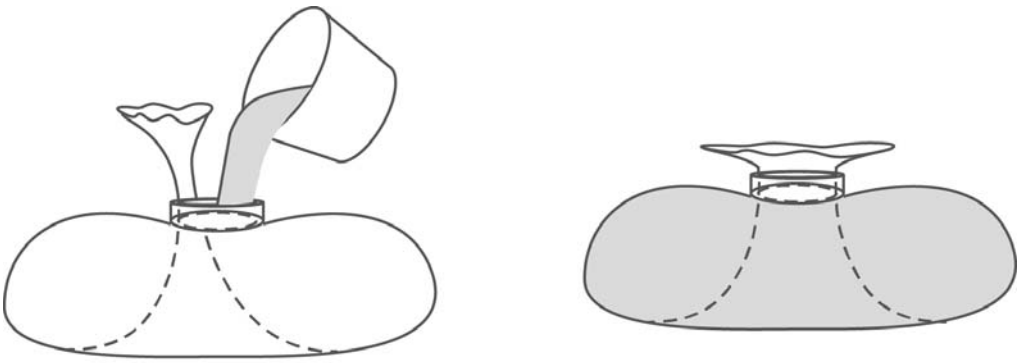

Figure 6.3 Concept C

A ring shaped opening in the middle of a circular cut enables the fabric to pass through, reaching a torus shape when closed. Pulling the fabric upwards the volume is adjusted and the air is forced out through the opening.

6.3.4 Concept D

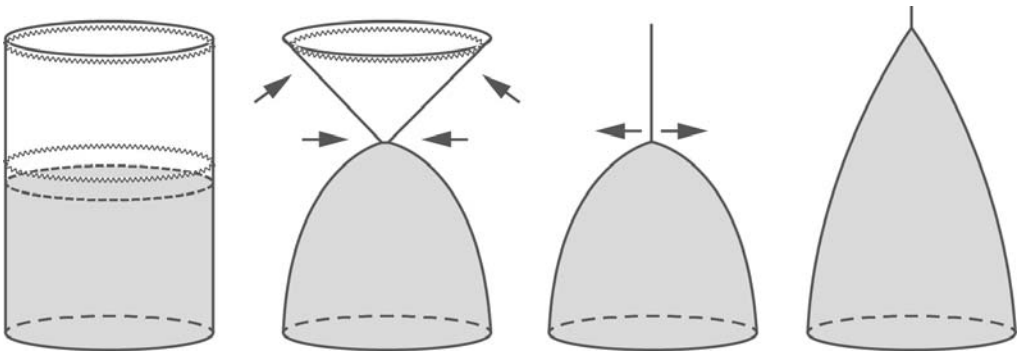

Figure 6.4 Concept D

The basic principle utilizes two closing sections. The pouch is filled so that the fruit surface aligns the first closing section. The pouch is then closed at the fruit surface and any embedded air is removed before the top section is closed. Finally, the first closing section is opened to get the wanted volume and shape.

6.3.5 Concept E

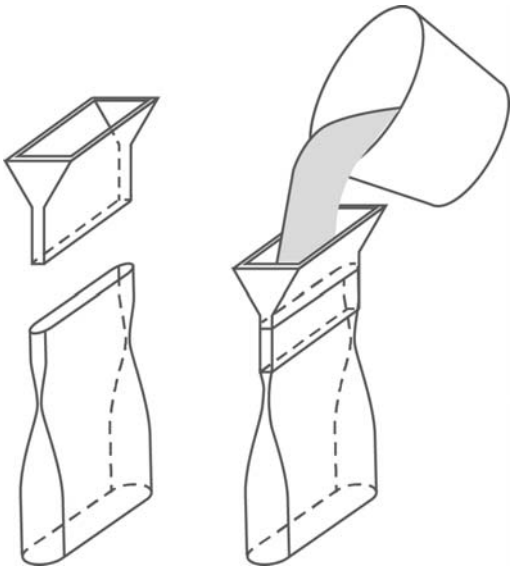

Figure 6.5 Concept E

For this concept, an external funnel is used together with a bag. The bag is made in a stretchy material and the upper section is self-sealing to a certain level. The bag slides over the funnel from below before filling. Then the juice/puree is poured into the funnel and the bag is removed. When removed, the bag automatically seals without entrapping air.

6.3.6 Concept F

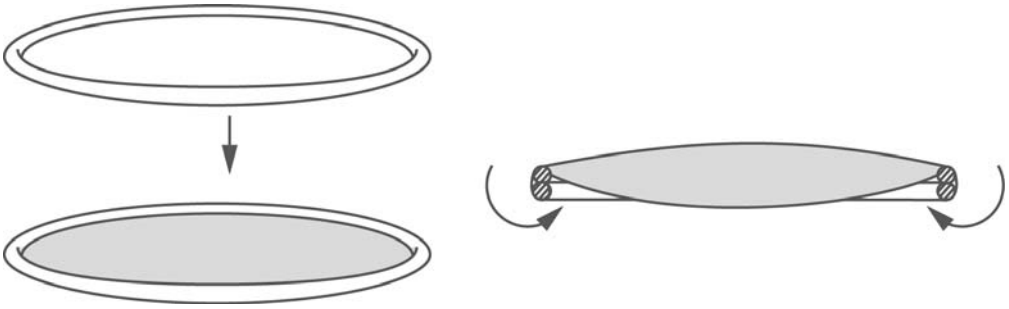

Figure 6.6 Concept F

Two separate circular sheets, fixated by rings, is sealed together by squeezing one over the other. The strength in this concept lies within the possibility to fully open it up for filling, emptying and washing.

6.3.7 Concept G

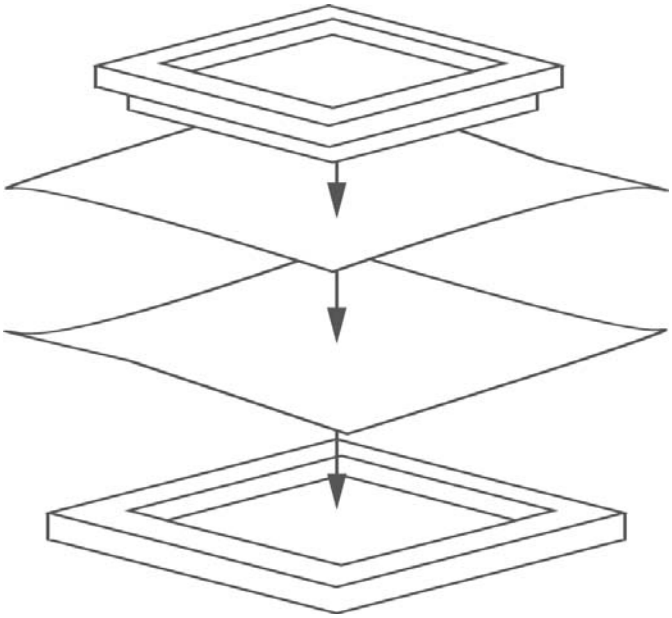

Figure 6.7 Concept G

Instead of modifying the fabric, this concept uses wooden frames to clamp two pieces of sheets together, having the juice/puree in the middle. This makes it possible to easily remove the fabric and change it if worn out.

6.3.8 Concept H

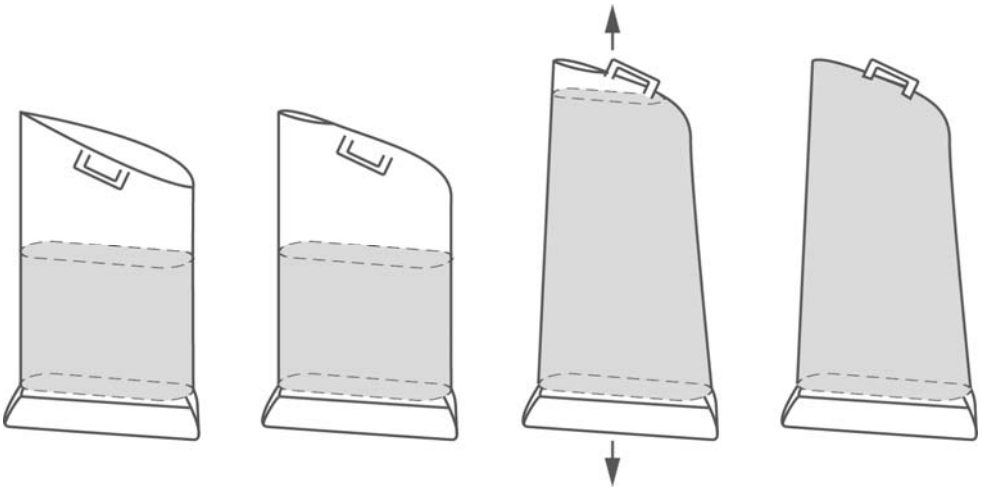

Figure 6.8 Concept H

The concept makes use of a stretchy material. When the pouch has been filled, one foot is placed in a back strap and the fabric is pulled upwards by hand. As a result the surface rises, and when it reaches the top the pouch is sealed. Using a beveled surface together with a zipper facilitates the handling.

6.3.9 Concept I

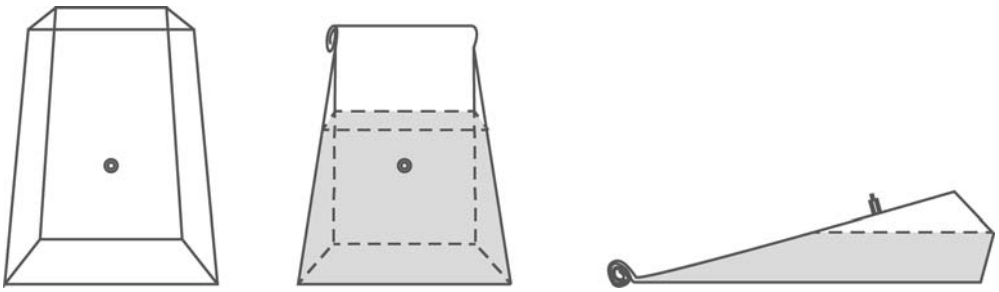

Figure 6.9 Concept I

The core in this concept is the valve feature. The valve lets the user to fill the pouch without any concern of entrapping air into it. Once the pouch is filled and closed, the user releases the entrapped air by pressing the air out of it.

6.3.10 Concept J

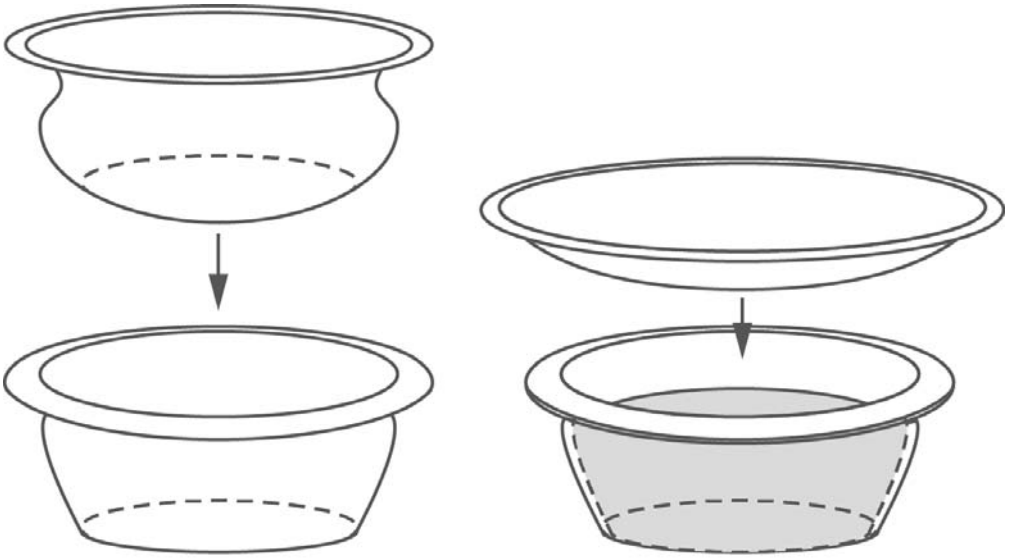

Figure 6.10 Concept J

The concept utilizes the buckets that are being used for fruit processing with the use of two separate sheets to encase the fruit juices/purees. One of the sheets is placed into the bowl before the juice/purees are made and when finished the second one is attached on top. The bucket gives the user control over the product and facilitates filling and sealing. The air is removed by smoothing out the surface by hand.

6.3.11 Reference Concept

In order to compare, a reference concept (Ref) was defined. The concept is based on a simple, first thought solution. The shape is rectangular with one sheet of fabric folded in the bottom to form a pouch with welded sides. The top is left open and is sealed with an external clamp.

6.4 Concept Screening

To evaluate which concepts to develop further, a *concept screening* was done. The scoring that was used is relative to the reference concept were the concepts were compared whether they were better or worse than the reference, symbolized by + or - respectively. Out of the 10 concepts, the ones that scored the highest and more importantly higher than the reference were chosen.

6.4.1 Selection Criteria

The Concept Screening is based on the selection criteria *filling*, *emptying*, *washing*, *sealing*, *minimize air* and *complexity*.

Filling is how manageable the product is when filling. This regards how easy it is for one person to do this, if it is stable, how variable the filling volume is and the feedback.

Emptying concerns how well the product is suited for emptying the different types of preserves. If it is possible to open up fully to ease the emptying of more dried preserves, if it is easy to squeeze out the softer ones or both. The ease of reaching all places or if special tools is needed.

Washing is primarily washing in bowls. If it fits and how accommodative it is. If it is possible to open up fully to easily reach all corners and edges. If it has many parts that gets in the way and if they are loose and needs to be treated differently.

Sealing is basically how well the sealing works. If it is solid and tightly sealed enough. How easy it is to manage and if it requires much strength for opening and closing. If the sealing wear on any other part or if it wears out over time.

Minimizing air regards how efficiently the air is removed. How well the user gets the feedback needed in order to do this properly. If the air is easily oriented towards the wanted place. If there is an increased risk for entrapped air and if these are easily missed.

Complexity touches all areas in terms of how complex the solution is. If it is easily understood and cognitively ergonomic. If the product consists of many parts and if these are standard components or in different materials and needs to be produced by different manufacturers. How difficult the product is to manufacture and if it is requires high precision. Last but not least how economically and environmentally sustainable the product will be.

6.4.2 Result

Table 6.1 Concept Screening

	Concept										
Selection Criteria	**Ref**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Filling	0	0	0	-	0	+	+	+	0	+	+
Emptying	0	0	+	0	0	-	+	+	0	0	+
Washing	0	+	+	+	0	-	-	+	0	-	0
Sealing	0	0	-	-	-	+	-	-	+	0	-
Minimizing Air	0	+	+	+	+	+	0	0	+	+	0
Complexity	0	0	+	0	0	-	0	0	-	0	0
Score	0	+2	+3	0	0	0	0	+2	+1	+1	+1
Rank	7	2	1	7	7	7	7	2	4	4	4
Continue		Yes	Yes					Yes			

As seen in Table 6.1, the concepts A, B and G got the highest ranking and therefore the concepts that were further developed. Concept H, I and J were better than the reference concept but were considered too little advantageous to proceed with.

6.5 Concept Development

After the screening, the selected concepts were developed further towards a tangible concepts and somewhat working prototypes. Varieties of single solutions were developed, compared and evaluated. All steps of the usage were covered by rough tests to simulate real life conditions.

6.5.1 Concept A+

In the proceeding concept development process, different varieties of *concept A* were prototyped, trying to come up with a solution that could be easily maneuvered by one single person.

6.5.1.1 Sliding Device

Much of the concern regarding the design was focused on how to construct the device that helps the user with the removal of air.

The first prototype to be developed was a design that utilizes the principle of two cylinders spinning around the same axis, one surrounding the other. By turning a knob their relative positions are shifted, keeping the fabric either clamped or free. The design is shown below in Figure 6.11.

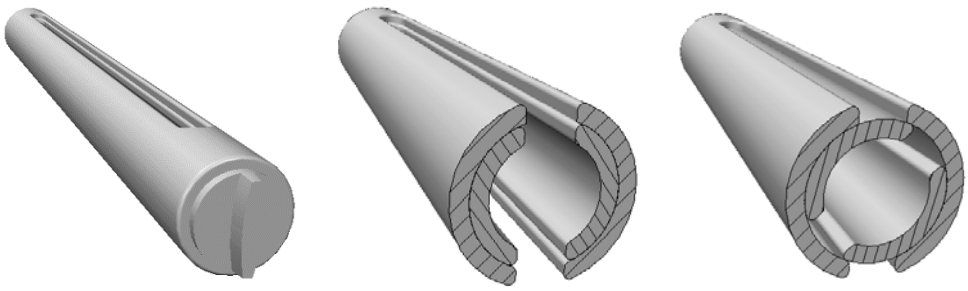

Figure 6.11 The sliding device in its entirety, opened- and closed state,-from left to right.

During tests of this device a few problems were highlighted. One major issue was that the friction between the cylinder and the fabric easily gets too high, making it hard to slide the device upwards. Furthermore, the turning motion required that the fabric had to be loose. Neither was the key grip optimal for the turning motion, since the grip is not appropriate to generate a great force. It was also realized that having the device totally free from the fabric was impractical in several aspects.

To make the design better, an upgraded version was developed. The design is made in one plastic piece, taking use of the plastic properties to form a hinge in the center. The hinge allows the device to fold so that the fabric is clamped together when the air is to be removed. A snap fitting is used to lock the part in that position, see Figure 6.12.

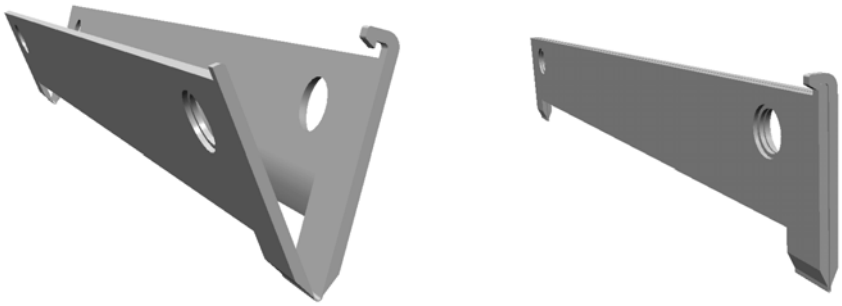

Figure 6.12 Alternative sliding device

The device has also gained one function. Instead of having a completely loose part the device can be mounted and unmounted to the opening of the pouch. During filling the device can work as a funnel to assist the user if kept in an open position.

6.5.1.2 Conclusion

As the focus of this concept is the air removal, this is also its greatest advantage. The sealing allows a stepless variation in degrees of opening that eases the filling. The clear design gives a high affordance, minimizing misuse. Since the mass center is closer to the top, the pouch might be difficult to handle for only one person.

The opening is limited by the sliding device and the concept becomes substantially more complex when increasing the width of the opening. Fine tolerances is also needed for the sliding device to work properly and could lead to complication of the production.

The small bottom of the opening limits the access to the preserve and eversion is required for cleaning. The sliding device also adds to the disincentive.

6.5.2 Concept B+

In the development of *concept B*, the biggest issues was the sealing, the shape and the orientation when filling. For the sealing, the main issue was compromising between the flexibility when opened and the tightness when closed.

6.5.2.1 Shape

When defining the shape of the concept, different types and varieties of these were evaluated. Since a core aspect of the concept is to avoid corners and sharp edges, most types but the elliptical shapes were rejected.

It is desired to have the shortest circumference possible to minimize the length of the sealing. For fixed volume and thickness, the surface area on an ellipse is dependent on the major (a) and the minor radius (b). The ratio between the area (A) and the circumference (C) is defined:

$$\frac{A}{C} \approx \frac{\pi\, a\, b}{\pi\left(3(a+b) - \sqrt{(3a+b)(a+3b)}\right)}$$

The ratio should be as high as possible and is therefore achieved when $a=b$, thus a circle.

6.5.2.2 Orientation

On the basis of the circle, three feasible ways were evaluated. One which the bag will stand in a horizontal position and two lying flat whereof one is filled having the bag fully opened and one partly closed.

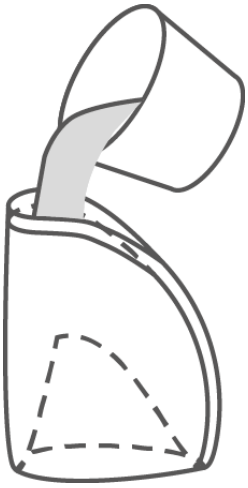

Figure 6.13 Filling, standing orientation

With the upstanding varieties, there are some problems with stability. The solution is dependent on a fairly stiff fabric to adopt the shape. A great stress is also put on the sealing in order to bend closer to a 150° angle.

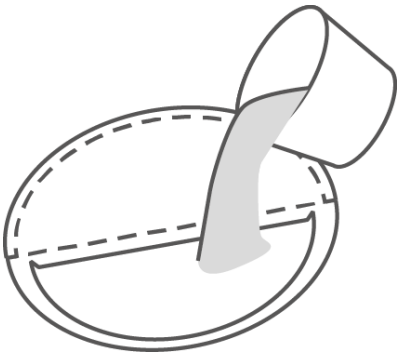

Figure 6.14 Filling, open state

The big filling surface that comes with the flat, open variety enables an indulgent filling but lacks the robustness in terms of the conditions of the surrounding. It will also be dependent on a rigid fixture to give the right thickness.

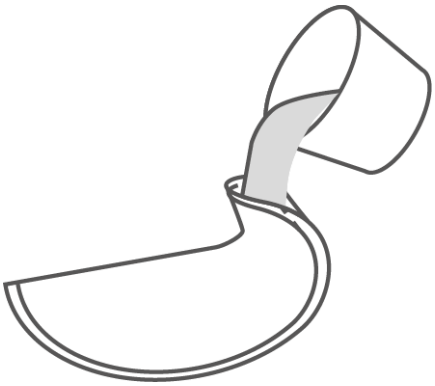

Figure 6.15 Filling, folded state

The other flat variety is more straightforward as it is based simply on holding up the edge when filling. Since it is fairly incomplex, more is required from the user but on the contrary it also makes it more straight forward and is easier to understand. This variety has proven to be the most easy and efficient in tests and requires the least from the seal and the fabric and therefore the path to continue on.

6.5.2.3 Zip Sealing

The zipper needs to fulfill certain requirements to work as intended. It has to be flexible enough, allowing twisting and bending, to make the product manageable during washing. The flexibility criteria is also crucial for the handling of the product when the air is to be removed. Furthermore, the zipper must ensure that the opening can be varied in size during filling and kept wide open without any self-sealing issues. The sealing must be strong enough to withstand the steady load from the content and forces that occur during lift.

Least, the sealing should be in no contact with the inside and the inner content. This is because of sanitary reasons. A zipper placed on the inside would most likely introduce small remote spaces which would have been hard to clean.

To see if any available sealing-solutions meet these requirements an inventory was made. The main issue when trying to find an adequate zipper was to find one without compromising between the flexibility when opened and to ensure a tight seal.

None of the zippers available on the market fulfilled the wished for requirements and therefore designing a new zipper was necessary. Since it had been set that the zipper should be operating from the outer side of the fabric, the starting point for the zipper was that it should clamp the fabric together, similar to Figure 6.16 consisting of a clamp and a rod.

Figure 6.16 Principal of clamp, fabric and rod

6.5.2.4 Conclusion

The biggest advantage for this concept is that it can be completely opened. This gives the user good accessibility when emptying the preserve and make the cleaning easy. Because of its simple and flexible design it allows the whole range of preserves as defined in chapter 5.4.1. There might be an initial need for explaining the handling but the learning curve is estimated to be steep. A critical disadvantage is the sealing that needs to cope with high demands in order to work properly. The circular cut of the fabric is not likely to utilize the fabric roll, which would lead to higher spillage during manufacturing.

6.5.3 Concept G+

In the development of *concept G*, the main issue was the adaptation to an uneven surface. Other core issues was the shape and method of sealing.

6.5.3.1 Shape

For the defining of the shape of this concept, the geometry was limited to relatively straight shapes. As the ratio between the area and the circumference is the highest when a four sided geometry is a square, this is where the shapes was based on. The creases of the fabric that the corners incurs is problematic. This could be solved by rounding the corners but an inner round adds complexity to the production. Instead, a compromise was done, choosing an octagonal shape. This breaks the angle of the corner in half so that the acceptable angle of 45° is obtained.

6.5.3.2 Oblique Level

The adaptation for a placement on an uneven surface is crucial for this concept. The oblique level of the fruit juice/puree that occurs is solved by elevating the frame to make it horizontal or making the thickness larger to increase the safety distance to the upper edge.

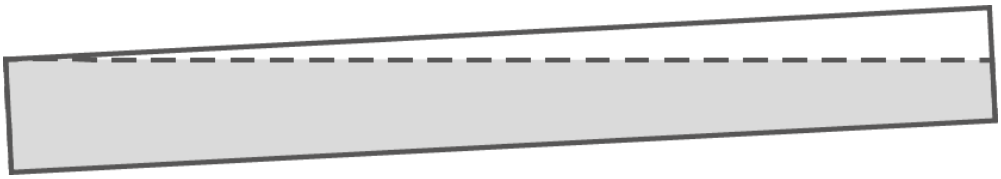

Figure 6.17 Principle of the oblique level

If tilted only 3° the thickness needs to be *½ sin(3°)* times the width thicker in order to cope with the slanted level. This means an extra centimeter is added to the thickness if the width is set to 380 mm. To this, an extra distance is added for a safety margin to avoid the need for precision when filling.

6.5.3.3 Sealing

Different kinds of sealing and straps were evaluated but through tests, the discovery that the steady load of the upper frame is enough for a tight seal. This solution might not be the best in terms of robustness but unbeatable when it comes to price, production, environment and use and consequently the chosen sealing method.

6.5.3.4 Conclusion

The biggest challenge with this concept is the aligning and the sensitivity when placed on a slanted surface. This causes several consequences including the precision when filling and removal of entrapped air. It will therefore be necessary to make the product proportionally bigger to avoid the need for this precision. This, in turn, causes a bit bulkiness in relation to received volume of preserve.

The open and accessible design have the advantages of emptying a solid preserve and cleaning of the fabric. If the fabric wears out it could be easily replaced. The wooden frame construction may require much maintenance due to weather conditions.

As for the production, a big benefit is that the fabric does not need any extra preparation or processing. It utilizes the bulk fabric with a simple and straight cut. On the other hand the design faces the difficulties with splices and folded fabric. An additional material, such as a wooden frame will make the production more suited for the local conditions and therefore likely to promote local job opportunities. This may imply another third party to rely on which could make the production sensitive. It will also be more materials to take into account in the end-of-life stage.

6.6 Concept Scoring

For the *concept scoring*, same selection criteria was used as for the *concept screening* (see chapter 6.4.1) but for this, all the ratings were weighted to fit the relative importance of the different selection criteria. It is important to mention that all the selection criteria are of great significance. Some are weighted low as some functions have little added value if they work better than just fulfilling the touchstones.

The rating scale, from 1 to 5, is based on the relative rating of the reference concept which is rated 3. 1 and 2 being much worse and worse than the reference and 4 and 5 being better and much better than the reference.

6.6.1 Result

Table 6.2 Concept Scoring

		Concept			
Selection Criteria	**Weight**	**Ref Rating**	**A+ Rating**	**B+ Rating**	**G+ Rating**
Filling	16%	3	3	3	5
Emptying	22%	3	3	5	3
Washing	18%	3	2	5	4
Sealing	10%	3	5	3	4
Minimize air	18%	3	5	5	2
Complexity	16%	3	2	4	2
	Score	3,0	3,2	4,3	3,3
	Rank	4	3	1	2
	Continue	No	No	Yes	No

As *Concept A+* was aiming on the minimization of air, it is basically a bit more complex variety of the reference. What was gained in sealing and minimizing air was lost in the complexity and washing.

The construction of *Concept G+* proved to be a bit complex mainly due to the need for fine tolerances. Consequently, the air was difficult to remove especially when the product was placed on an uneven surface.

Concept B+ proved to work well in the tests and on no criteria worse than the reference. It got the definite highest score and is therefore the concept that was developed further. The concept will be divided into two derivatives. One which will follow up the concept with the user and functionality as highest priority (B1) and one with focus to reduce the complexity (B2). These will be presented in the following chapters.

7 Final Concept

In this chapter the further development and refinement for the chosen concept is described. Details are determined in principle to a level enough for the reach of a functional concept.

7.1 Objective

Concept B+ was divided into two derivatives whereof *concept B1* was the extended version that followed up and defined the initial concept.

The detail design was refined, prototyped and tested iteratively. Since the sealing is of most importance for the concept, this is where most focus was put. Other areas of interest were also looked into more specific, such as the overall shape, size and cognitive ergonomics.

7.2 Shape and Size

The volume was set to a 4 liter capacity. This was mainly reduced for the sake of the handling. The size will also be convenient when washing.

Likewise, calculating the size, the calculations was based on a thickness, *t*, of 35 millimeters to have a margin to the maximum 40 millimeters since the thickness is sensitive for the drying and could be a risk of being breached by the user.

Assuming the edge adopts the rounded shape of a semicircle, the removed area times the circumference is needed to withdraw from the volume, *V*:

$$V = \frac{\pi \cdot r^2}{2} \cdot t - \left(\frac{t^2}{2} - \frac{\pi}{2}\left(\frac{t}{2}\right)^2\right)(\pi \cdot r + 2r)$$

This leads to a radius, *r,* of 280 millimeters.

7.3 Zip Sealing

Optimal for the zip sealing design would be if the clamp and the rod take use of one material solely throughout a homogeneous section. However, as being mentioned earlier, the challenge with the zip sealing is the trade-off between flexibility and stiffness.

7.3.1 Design

Trying to resolve the zipper just by finding a material with perfectly balanced properties seems hard to achieve. Instead the approach was that the zip sealing must be modified somehow, focusing on the clamp. This modification could be done in numerous ways, most of which result in a variation in the cross-section. The thought of ideas were: sectionalizing by cutting, either fully or partly, having a varied thickness or by mixing materials with different properties. After prototyping, a clamp designed in two materials with different properties together with a homogeneous rod was decided upon. This since it met the demands for the overall design in the most satisfactory manner.

Another matter regarding the zip sealing was whether it should be free, exposed to the outside environment, or sewn into the fabric. Solutions for each were prototyped and a comparison between the two options was made, based on the virtues and disadvantages.

Free:

- exposed to greater stresses (especially the ends of the clamp and rod will be weak spots)
- less robust
- dirt can get in and affect the sealing function
- greater risk of misuse
+ better affordance
+ easier to manufacture
+ less problematic regarding the ends and their movement in relation to each other in open and closed position
+ easier to repair if necessary

Sewn in:

- lack of affordance (less visibility)
- require more manufacturing operations
- resolving the ends will be more problematic (keeping the rod and the clamp mounted to each other will probably needed)
- less suited for switching a broken component
+ more sustainable
+ more robust
+ less sensitive to dirt
+ added possibilities to print on the fabric, change the color etcetera
+ minimized risk for misuse, as a result of added constraints
+ ease cleaning

The benefits of having the zip sealing sewn into the fabric were considered to outweigh the disadvantages. It was therefore wished for to have it sewn in.

The zip sealing consists of three parts: a circular rod and a clamp with an additional number of shorter support sections, seen in Figure 7.1. The clamp prevent juices/purees from penetrating through the sealing and the support sections to reinforce the design. The support sections are attached to the long clamp at equal

distances. The clamp have a flat surface towards the fabric to facilitate the orientation with the active side inwards. A chamfer is made on the inner edges to ease the placement of the rod. In order to not neglect neither left-hand nor right-hand users, the profiles have a symmetric cross-section.

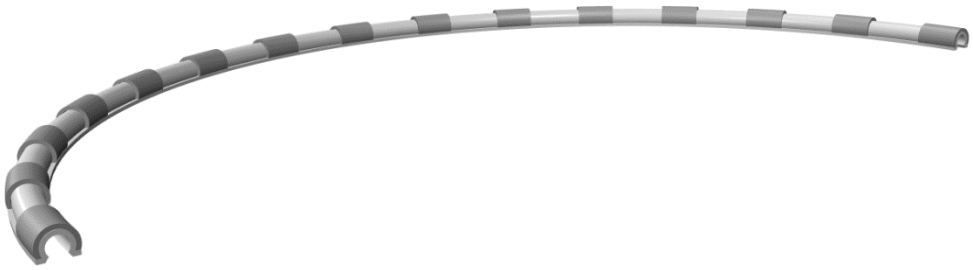

Figure 7.1 The clamp with support sections

The size for the rod and clamp was to a great extent based on usability testing, with a variety of different sizes. A smaller sealing was perceived as neat but in the same time hard to maneuver and caused discomfort when pushing. Being too big, the sealing instead was perceived as bulky. The illustration in **Figure 7.2** shows a size that the authors thought was suitable. The size and thickness is also closely related to the stiffness and function of the zipper.

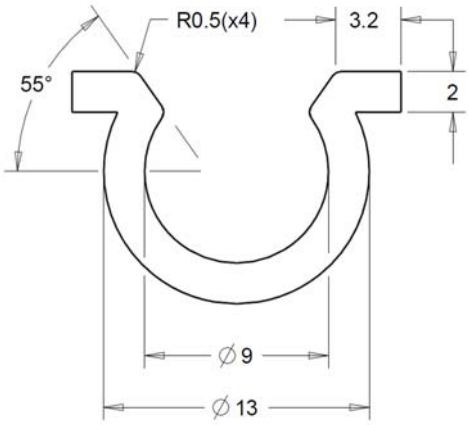

Figure 7.2 The measurements of the clamp profile

7.3.2 Strips

The zip sealing is hidden under a strip of fabric that wraps around the pouch. Since hiding the zipper affect the visibility and affordance, the strip is attached to closely embrace the zipper to give maximum visibility. Still room is left to allow the fabric to be withdrawn from both sides of the zipper. The strip will be marked with a color that distinguishes from the rest of the bag to indicate the active part.

7.3.3 Ends

In order for the sealing to function and let no juice/puree through, the profile must overlaps the ends of the fabric when folded. This is achieved by designing the profiles to encompass slightly more than half a circuit. To facilitate the rotational motion which constitutes the folding, the clamp is a bit longer than the rod. Furthermore, the rod's ends are rounded to orientate it into the clamp.

This overlaps puts some requirements on the strip in the two encountering positions, forcing the fabric outwards. The solution for this is to have two strips instead of one and leave a small gap in between which leaves room for the clamps to stick out. This gap is then covered with a looser piece of fabric. The advantage with this is that it also provide the user with an indication of where to fold.

7.3.4 Material Selection

Setting the correct material and material compositions for the parts are important to obtain suitable properties. For both the rod and the long clamp profile a TPE (thermoplastic elastomer) can most probably be used. The TPE:s can be compounded to have the following properties [24, pp. 39-44]:

- can be obtained in a great span of hardness and E-module
- can be reprocessed (recycling the material)
- possible to use in food applications
- UV-resistant
- high resistance to chemicals
- resistant to wear

The properties for TPE materials, for example flexural modulus, are closely related to the softness or hardness value on the Shore durometer scale [24, p. 39]. Following the advice from different suppliers and people in the industry the rod is made with a quality around 70A. For the long clamp profile a harder material with a value around 60-70D is appropriate.

A more thorough material research will be necessary to decide what TPE suits the application the best and how it should be compounded, this however will not be part of this report.

7.3.5 Straps

To make it easier to open the pouch straps are attached at the ends (when folded). The straps are oriented on each side and are pulled to open the pouch. Preferably, the straps are made in the same polyester material as the pouch to facilitate potential recycling.

7.4 Window

Since the design in itself does not prevent the user from overfilling the pouch, feedback is necessary to minimize the risk of overfilling. The decision was made to place a window on the pouch to give this feedback. The window is placed on the long straight side of the pouch, with the width stretching over on both sides. The placement gives good visibility from all angles, permissive to both right-hand and left-hand users.

A proposal is that the window is marked from 1 to 4, correspondingly to both the volume (in liters) and the thickness (in centimeters). The end of the scale is clearly marked to elucidate that it should be filled no further. The scale also shifts color in the end, from green to red, which tells the user to stop. The exact graphical appearance however, will not be designed during this master thesis project but is left for upcoming development.

The window will preferably be made of a stripe of semi-transparent fabric or PVC.

7.5 Fabric

The color of the fabric is undefined and could come in any color. It is advised that tests should be done to control the temperature that the content gets with different colors. Rough tests indicates that a darker color raises the temperature but a too dark color might get an unwanted high temperature.

When handling, testing and experimenting with different fabrics it was found that the thickness should be around 180g/m^2. This is mainly because the fabric should be rigid enough to withstand the conditions but flexible to ease the handling when removing the air.

7.6 Manufacturing

Assuming that the pouch will be produced in bigger quantities, manufacturing methods are here presented that seems suitable.

The profiles for the zip sealing have constant cross-sections, why extrusion molding is the natural choice of manufacturing method. The rod has a round cross-section so finding an existing die will be easy if a standard diameter is used for the rod. The rods are then rounded in the ends with lathing. The clamp will require manufacturing of a die for the extrusion. Since the soft material allows bending to a high degree, the profiles can be extruded without any consideration to the round shape.

The support sections will be extruded as well. As they are designed for the moment, they have an arc shape to fit the clamp. This will require the profiles to undergo further processing after extrusion, flanging to be more exact, which will increase the processing costs. Depending on price for this operation, the profiles can be manufactured straight instead. This will only affect the function marginally.

With the reservation of that the material might be another than proposed, a stiffer material may be chosen, and it is possible that the clamp profile must undergo flanging as well. However, this is not seen as likely.

The round sheet constituting the pouch will be cut from a roll of fabric.

For the window, straps, and strips welding will be used for attachment with the bag. Since the seams are irregular, high-frequency welding that take use of a die to stamp the welds is recommended [25].

7.7 Presentation

The bag is laid flat and the upper part is folded so that the opening is facing upwards (Figure 7.3). The bag is then filled with the fruit juice/puree and then sealed with the exception for a small part that is left open to enable the air to be easily removed. This is done by a gentle pressure, forcing the air up and out (Figure 7.4).

After the bag has been filled and closed it is placed on a suitable place for the drying (Figure 7.5). The soft material allows the user to feel when the preserve has the desired consistency.

For the removal of the preserve the bag is opened to a suitable state; little to squeeze out the softer preserves and completely for the harder ones (Figure 7.6). The later state is also the case for the cleaning, when the bag is fully opened for maximal flexibility and exposure of all surfaces.

Figure 7.3 Filling state

Figure 7.4 Air removal

Figure 7.5 Drying state

Figure 7.6 Open state

8 Alternative Final Concept

In this chapter the further development and refinement for an alternative to the chosen concept is described. The divergent details is determined to describe the principle to the level enough for the reach of a functional concept.

8.1 Objective

As the other derivative of *Concept B+, concept B2* had the focus to reduce the complexity as to be an alternative to *concept B1*. Since the zip sealing is a critical issue of *concept B+*, *B2* is based on the reduction of the impact of function with the trade-off of the possibilities for a fully open solution. The detail design was also here refined, prototyped and tested iteratively.

8.2 Shape and Size

This pouch is, as for the previous concept *B+*, manufactured from a single sheet of fabric with a zip sealing folded in, in the top. The dimensions of the bag is based on a square and an isosceles, right triangle. This is based on that a square has a high circumference-area ratio and that the tapering of the triangle shape facilitates the air removal.

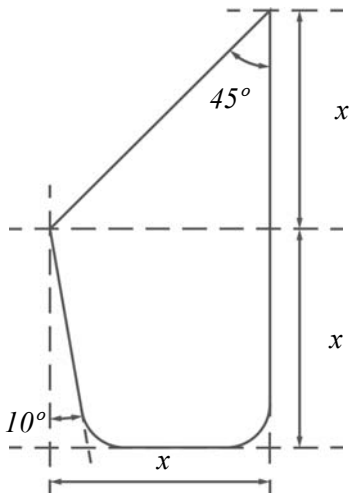

Figure 8.1 Bag measurements

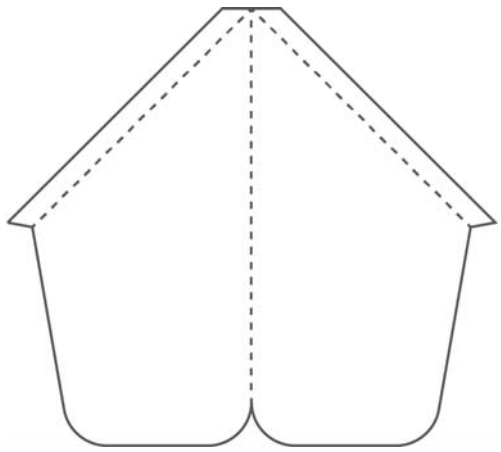

Figure 8.2 Unfolded bag

The side of the square that meets the sealing is tilted 10° inwards to ease the removal of the stiffer preserves. The bottom corners is rounded to reduce the corners.

Approximating the volume to:

$$V \approx t\left(x^2 + \frac{x^2}{2}\right) - t\left(\left(\frac{x^2 \sin 10°}{2}\right) - \left(r^2 - 2\frac{r^2\pi}{4}\right)\right)$$
$$- \left(2x + 2\frac{r\pi}{2} + \left(x - x\sin 10° - \frac{r\pi}{2}\right) + x\cos 10° + x\sqrt{2}\right)\left(\frac{t^2}{2}\right.$$
$$\left. - \frac{\left(\frac{t}{2}\right)^2 \pi}{2}\right)$$

Where x is the sides of the square and the triangle and t the thickness. With a volume, V, of 4 liters, x=294 millimeters.

8.3 Sealing

Due to the smaller size of the sealing, this concept is not in the same need of having a flexible zipper for washing and handling. The zipper must be flexible enough though to permit the bag to be completely opened.

The solution for the zip sealing is as for *Concept B+* rooted in an extruded clamp together with a rod. After the extrusion the clamp is partly cut from the bottom and top, leaving parts in to connect the sections interchangeably as seen in **Figure 8.3**. The cut will preferably be rounded to avoid sharp edges that could be sensitive fracture lines [24, p. 162]. This allows the clamp to bend sufficiently in two directions, as seen in **Figure 8.4**. This will in turn allow the opening to be flexible enough for its varied states. The same principle applies for the rod but the flexibility is solved with the use of a flexible material, approximately around same hardness as for *Concept B+*.

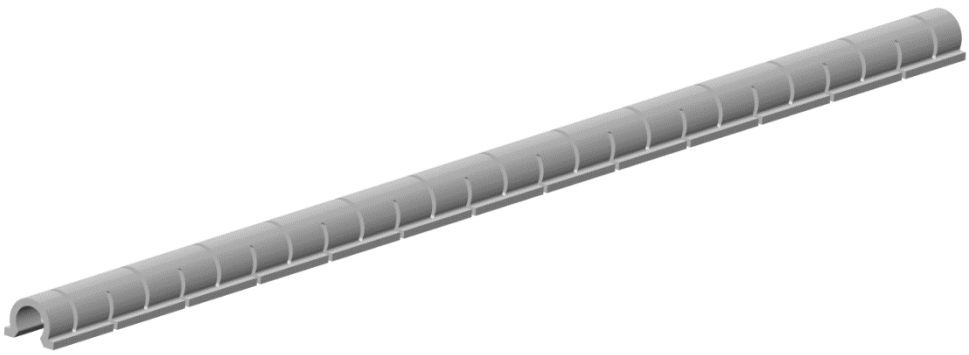

Figure 8.3 Clamp, partly cut from the bottom and top

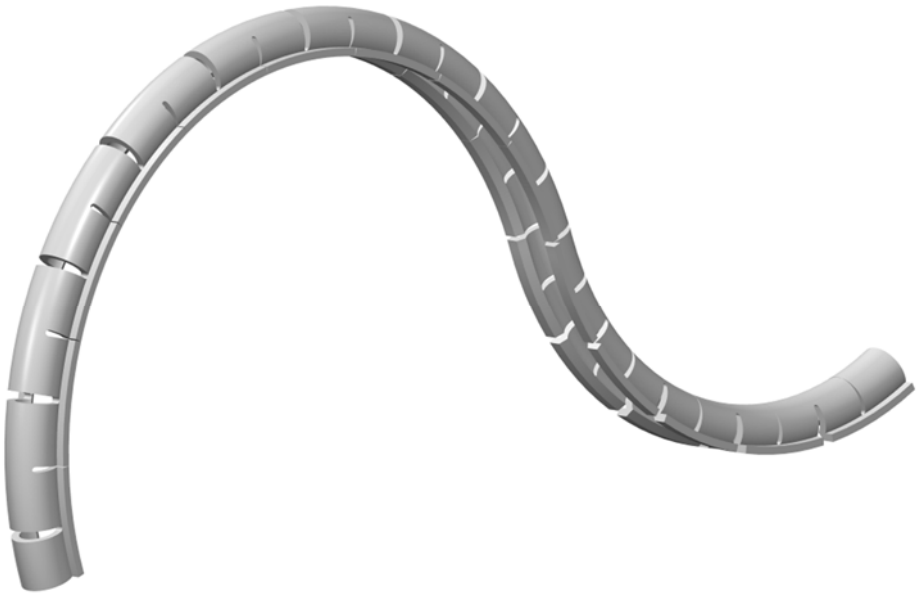

Figure 8.4 Bended clamp

The material for the clamp is made in a stiffer material than for Concept B+ so that the clamp itself can create enough force to ensure a tight seal. Similar extruded profiles with the same functional characteristics have been found in HDPE, why this might be a strong material candidate. HDPE can further be used in food applications and can be modified to be UV-resistant, [24, p. 21]. This will however require more comprehensive research.

8.4 Foldings

The foldings cover the zip sealing from the outer environment and, as for *Concept B+*, this enclosement is revealing the shape of the zip sealing by closely embracing it with the fabric. The folding are colored to be distinguished from the overall pouch and indicate the active surface.

When the zip sealing is bended, the length changes: extends on one side and shortens on the other. Since the folding are attached to the zip sealing, the fabric must flex accordingly. Following expression applies to the fabric's length of the extension:

$$\Delta l = d \cdot \alpha$$

Where d is the depth of the cut and α the angle of circumference. When the pouch is in a totally open condition the fabric extends about 30 millimeters over a length of 420 millimeters. This means that the folding fabric must be able to stretch just over seven percent. It may therefore be necessary to produce the folding in another fabric than the overall pouch.

8.5 Presentation

The principle handling is the same as for *concept B1*. The bag is laid flat and the upper part is folded so that the opening is facing upwards (Figure 8.5). The bag is filled with the fruit juice/puree and then sealed except for a small part that enables the air to be easily removed. This is done by a gentle pressure, forcing the air up and out (Figure 8.6).

After the bag has been filled and closed it is placed on a suitable place for the drying (Figure 8.7). The soft material allows the user to feel when the preserve has the desired consistency.

For the removal of the preserve the bag is opened little to squeeze out the softer preserves and for the harder ones the bag has to be everted (Figure 8.8). Since the opening is wide and the angles between the opening and the sides is less than 90°, this will be relatively effortless.

The washing will also be done in the everted state for maximal exposure of the preserves abutting surfaces.

Figure 8.5 Filling state

Figure 8.6 Air removal

Figure 8.7 Drying state

Figure 8.8 Everted state

9 Discussion and Reflections

In this chapter, a subjective view of the authors is presented. Discussions regarding the result and conclusion as well as general reflections of the project its complications and the lessons learned.

9.1 Further Development

The two presented concepts are the result of the work of a limited period of time. Up till now the concepts have been developed to the point of a technical *proof of concept*. We believe that the next step in the product development process will be to ensure that the product proves worthy to the users. Manufacturing prototypes and conducting user tests in the user context will therefore be necessary. Tests will most certainly expose problems and difficulties with the prototypes that needs to be solved. Hopefully, one of the concepts is chosen to pursue with for refinement. If not, functional elements may qualify to be part in a new prototype.

Except user tests the prototypes should be further investigated in a lab environment to test their overall function and efficiency. Even though the products have been tested to a great extent and been proved to withstand water from penetrating under pressure and encouraged evaporation, no standard such the IP code has been applicable. Moreover, the research that is now being conducted on the ability to dry different fruits may add additional constraints to the pouches. Referring to Fick's laws [11], the shape of the pouch plays a crucial role for the drying, so it has to be established that the shape reassure a uniform drying.

If the decision is made to continue with one/both of the prototypes several key areas needs to be looked into for refinement. The most important stakeholder to consult is probably the manufacturer of the fabric, which has so far not been possible due to confidentiality reasons. Since all research regarding multilayer textiles has been done on a literature level, making sure that the design cope with reality is vital, not least from a price point of view.

Detail design will be next and include material selection and testing such as measuring stresses and strains for the parts, especially fatigue for the support sections for *Concept B+* and clamp profile in *Concept B2* and also fracture sensitivity in the cuttings for *Concept B2*. Furthermore, the quantity of units has not been decided upon and if the production will be in a very small scale the manufacturing methods may change.

Decisions concerning the detail appearance, such as color, print and other graphic design has been put aside. This is simply because of the fact that the exact use and

implementation has not been set. For instance, it is possible that the pouch will be distributed through a charity organization and they want to put their graphical profile on it.

Moreover, the alternative of implementing pouches in sun dryers are being investigated by the team but has so far been treated as a separate project. Adaption to suit that purpose may be required later on. Making some sort of standing for the pouches can also introduce small changes in the design.

9.2 Ethical Aspects

We strongly believe that it is important to establish what the intentions for the product are. This must be conveyed to align the project organization and be reflected on the product and the introduction on the market. This affects not at least what happens if the product breaks and at the end of usage. To minimize the environmental impact the concerns regarding *end of life* must be thoroughly premeditated. As what we have understood, Mozambique has a very underdeveloped waste management and the majority of the waste either goes to landfill, is burned or simply thrown in the nature. This insight places high demands on the moral obligations when introducing a new product. The potential users are in a vulnerable position and little or rather no obligations should be placed on them. Instead, the strategy for waste management could be to encourage the users by adding value somehow. The product must not solve a problem by adding another and the different dilemmas should be carefully weighed against each other. We would strongly recommend doing a *life-cycle assessment* and aim for a *cradle-to-cradle design*.

We hope to see that the project evolves to be of a charitable nature and on the basis of the perceptions received during our field studies we would recommend an implementation model that includes cooperation with an established help organization.

9.3 Project Planning and Execution

In the initialization of the project, it became clear that it would be vital to conduct field studies to get a deeper understanding of the user. In order to get contacts for, plan and not at least finance the field studies, more time than expected had to be spent on this. Why the initial phase was a bit prolonged. Initially, we had planned to work in an iterative manner, completing the first product development cycle before the field studies. It soon became clear that this could not be achieved in time and the project changed to have a more traditional *water fall* process.

Except from the change of plans in the beginning the work has, more or less, progressed according to our new time plan. Furthermore, the teamwork between the co-authors has been satisfactory. Most of the work was performed together, why the different parts in the report cannot easily be distinguished or derived to either one of us. However, we had different areas of responsibility during the thesis, for instance one person was responsible for the technical research and the other for user research when conducting literature research.

9.4 Learnings

From this project we bring a lot of learnings that will aid and help us to improve the quality of future projects to come. Regardless of what project and what it intend for, it is very important that all involved are aware of the projects framework from start. This seems like a statement of the obvious, but it is easy to become blinded by various reasons, such as the project's attractiveness and potential, and forget to have this in mind. In order to make the framework clear, a number of things must be brought to attention. This can be a bit uncomfortable since one might think that it can be perceived as being critical, especially as applicant. One might also think that this will decrease one's chances to be involved in the project. However, we think that casting light on potential problems is better to be done from start and that it will be beneficial for all parties. Moreover, we strongly believe that a serious recruiter will think of you as committed if these important subjects are brought up.

Below we suggest a few key points that have come to be our lessons learned.

9.4.1 Aim

Before one enters a product development project the exact aim and purpose with the project as a whole must be understood. Furthermore, knowledge of what has been done up to that point and what kind of work that is being carried out for that moment being is crucial. This is to make sure that one's expectations and picture of the project is consistent with the actual project. We also think that this helps to show if enough has been done on beforehand in order to do what is expected.

About the expectations from both the parties, they should be pinpointed and agreed upon. Regardless of how clear the expectations appear to be, the likeliness that all of them are mutual is low. If the expectations are a bit vague, we think that follow-up questions like "why do you want my expertise?" can help to clarify these. Most important is that the expectations are consistent when starting the project.

9.4.2 Team Constellation

Making clear which people that constitutes the team is very important. This determines what competences are in the group but it can also help to give a general idea of the project's credibility. Moreover, we think that one should be aware of the structure of the project organization and how the team collaboration look like before entering a project. In the end, the working environment is just as important as the project itself and must be satisfying and encouraging.

9.4.3 Means

In order to do a good job, having access to the necessary means are vital. This include everything from prototype material to technical information. This should be brought up and discussed as early as possible so both parties know what will be at their disposal and what is demanded. If this is not done, there is a high risk that one ends up in a position where the resources needed cannot be provided. This can ultimately postpone the work or in worst case lead to a total stagnation and cancellation of the project.

9.4.4 Role

Even though a company or organization have recruited a person into a project it does not mean that they have a clear picture of who this is, what their competences are and his/her methods of carrying out the work are. Consequently, we think that it is very important to clearly explain one's role, especially in interdisciplinary projects where different disciplines have deviating working cultures and approaches. As designer this might be even more important since a lot of design work mean using nonconventional methods such as quick and dirty tests, which might be considered as unscientific or incorrect for others. Moreover, it is, for a designer, very important to grasp the whole picture of what is being designed in order to do a proper and relevant work. This can be perceived as intrusive and/or irrelevant for some that are accustomed to their narrow field of expertise, especially when being asked about things that are within this field. This closely relates to previously mentioned topic about means, but accept from hindering the progression in work, defaulted information could undermine a designer's creativity.

9.4.5 Confidentiality

Most projects include some sort of confidentiality and confidentiality agreement. Even though the confidentiality agreement is clear, a thorough conversation about what information this agreement involve should take place.

However, this conversation should not only focus on the agreement. It should also be discussed if there is any information that one will not be granted. Because, if there is information that one cannot take part of, this might affect one's ability to perform.

Except from confidentiality which concerns legislation a general discretion can also be desired by the company. What this discretion imply should also be talked through to avoid misunderstandings.

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Appendix A: Interview Questions

		Initial
1	O	Have you had any experience with similar projects like ours?
2	O	Could you tell us about your family?
4	O	Can you describe your family? Who is doing what?
3	O	Are your children in school?
		Previous experience
5	W	Are you familiar with different programmes? (FTF, UNICEF)
6	W	Do you get any support from any organisations?
7	W	Do you collaborate with other farmers or communities?
8	W	Do you trade? Fruits? What fruits? In what form? To what?
		Different days
9	W	Could you tell us about a typical day?
10	W	...and a good day?
11	W	...and when you celebrate something?
12	W	What is a bad day?
13	W	How does a day with floodings look like? Drought?

14	W	What are your hopes for the future?	
15	D	Could you guide us through a harvest? What?	
16	D	During what time at year do you harvest? When?	
		Fruits	
17	D	What fruits do you grow?	
18	D	What happens with the fruit when harvested?	
19	D	Do you make any other products of the fruit? Do you dry? Make marmelade? Puree?	
20	D	How do you do this?	
21	D	What is difficult/easy with this?	
		Storing	
22	D	How do you store your fruit? Do you store fruits differently?	
23	D	Can you show us where you store your fruit?	*
24	D	What makes the fruit go bad? Mold, insects, pests, water, yeast?	
25	D	Are any of the stored fruits spoiled?	
26	D	What do you consider a bad fruit?	
27	D	If you can choose any fruit in any form to eat, what would you choose?	
		Equipment	
28	D	Could you show us your equipment that you use to refine fruits?	*
29	D	What is good about that equipment? What is bad about that equipment?	
30	D	What changes would you do to that equipment?	

31	D	Have you had any other technology for the same purpose?	
32	D	Where does that equipment come from?	
33	W	Have you heard of new ways of doing things or new technologies in the past year? How have you heard about them?	
34	W	When did you last hear about this?	
		Business	
35	D	What are your source of income?	
36	D	Do you sell any fruits to anyone? The market? Why (/not)?	
37	D	What are you selling? For what? In what form? Would refined fruit give more?	
38	D	What are threatening the sales? Bad fruit?	
39	D	If you had means to change anything in order to earn more money, what would you change?	
		Keeping Clean	
40	D	Could you show us where you do your laundry?	*
41	D	Can you show us your kitchen?	*
42	D	Could you show us where you do your dishes?	*
43	D	Do you use any chemicals when doing your laundry/dishes?	
44	D	How would you like to clean this material?	
45	D	What make it hard to keep stuff clean?	
46	D	What do you experience difficult about making the laundry?	

		Means
47	D	What materials do you use if you build something your own and where do you get it?
48	D	What tools do you have? Can you show us?
49	D	What physical object means the most to you?
		Rest
50	D	How do you keep objects clean?
51	D	Where do you clean yourself?
52	D	What would you consider clean?

Appendix B: Insights

Fruit Processing Business Leader

Statement/Observation	Insight
"We are propagating fruit trees for different areas of use and harvest periods"	They want to extend the period of access to fruit
	Different varieties suits different end products
"We wash the fruit in chlorinated water before processing"	The fruit is ensured to be clean before processing
"We need to add 30% of water to the mapfilwa pulp before drying"	Some fruits are being mixed with water in order to dry properly
"Mapfilwa is rehydrated after drying"	Rehydration is common practice
"The government says 'the people is even eating wild fruit to survive'"	The view of Mozambique's agriculture is problematic
"Some people believe that having a mapfilwa tree on your land means bad luck and they also believe that wild fruits should not be planted actively"	People are superstitious about what fruits to grow
"Marula fruit have big problems with worms and is therefore difficult to produce in large quantities"	Marula fruits needs pesticides for commercial production
"Masala have a lot of seeds in proportion to pulp so they are difficult to take out in large quantities"	Masala fruits is not financially profitable for commercial use

“It is difficult to standardize the fruits of Mozambique so the industry and foreign investors are sceptic”	There is many varieties to the different fruits
“Fruits are almost exclusively being sold fresh”	Processed fruit are not common

Smallholders

Statement/Observation	**Insight**
“We are eating flour made from fruits in hard times”	Fruit is an essential part of the diet
“We import different flour from South Africa and mix these to sell in smaller quantities”	There is a demand for mixed flour
	People are willing to eat processed fruits
	Mozambique is dependant on import from South Africa amongst other
“I sell the fruit on the informal market myself”	She takes care of the whole process on her own
“I get my water from the village well where it is always available”	There is no lack of fresh water
“The only tree I have planted is a cashew tree, I could plant other trees but there is no need for it”	There is a great access to fruits close by during season
“The fruit is easy to sell at the informal market”	There is no need to sell processed fruit if it does not increase the price
“Dried mapapua is the most beneficial to sell”	Processed fruit can increase the price
The fruit was drying in the sun, simply on woven plastic sheets	Pests are not a big concern
	The drying methods are very simple
Washing is done in a bucket with water and detergents	Hygiene is maintained with chemicals
“When the fruit is ripe there is more fruit than I can harvest”	The fruit supply is not the bottleneck during harvest season
“We get some support from the government and the university like tools, sugar and knowledge”	There is some established contact between the public sector and (at least some) farmers

“During hard times half a spoon of mapapua flour makes me last for half a day”	Fruits are an important source of nutrition
	Dried fruit is not necessarily prepared before it is eaten
They are drying the mapapua in the sun for two weeks. Two products were made from the dried fruit: 1. Flour was grinded in a large pestle and a mortar (sold for 100 MT/litre)	Same fruit are being processed to different products
2. An oily paste by drying in the heat of fire for one hour before grinding like the flour (sold for 120 MT/liter)	A substantial amount of time and effort is invested for processing
Buckets, plastic bags and glass jars were used for storage	storage solutions exist
Christina used her hands for separation of pulps from seeds and peel and for squeezing the pulp to a purée	No tools are being used in the preparation of fruit purées/jams
“We sun-dry the fruit on the roof in order to keep it away from the children and the goats”	Drying the fruits on the ground can be problematic
“Since both of our husbands past away we do not have time to make jam”	Lack of time can be crucial for fruit processing
“It is far to walk to the fruit trees but we carry a bucket [of 20 kg] a time”	Ditto
“We do not dry massala because it easily ferments”	Some fruits are not suitable for drying with the current methods
“Worst part of the year is March to July because then we only eat mapfilwa”	Mapfilwa is a commonly used fruit in hard times

Fresh water were being used to clean the fruits and dissolving the pulp	Ditto
“If you have a marula tree on your land it is your job to make the okani [fermented liquor] for the village feasts”	There are many deeply rooted traditions bound to the products that are being made

Fruit Processing Foreman

Statement/Observation	**Insight**
“We were forced to shut down [the processing industry] because the pasteurisation machine broke down”	Lack of financial support makes advanced processes fragile

Other

Statement/Observation	**Insight**
The common way to carry loads is on top of the head	Ditto
All the villages visited had a local chief, advising the farmers and working in contact with the government	The local chief could be a connection for information
A common place to store food was over the kitchen fire, letting the smoke to pass through	Ditto
All the people observed on the fields were women	Ditto
The garbage collection was underdeveloped and litter filled up the roads	Ditto
The small scale holders made everything by hand	They lack more advanced tools

Appendix C: Time Plan

Table C.1 Initial time plan

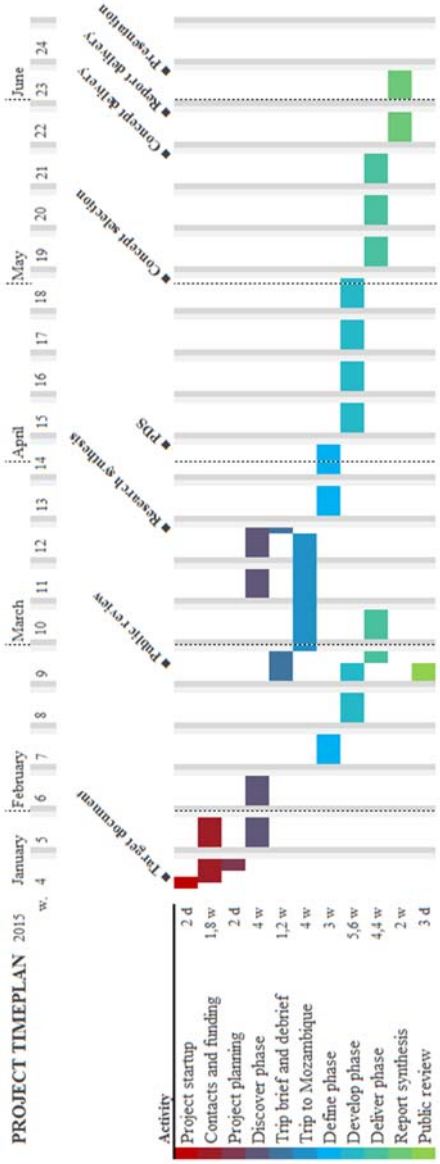

Table C.2 Revised time plan and actual outcome