Working towards SDG Target 12.3 baseline values: Quantifying food losses in the fruit processing stage of the food supply chain in South Africa

by

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Declaration

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Date: March 2023

Abstract

The prevalence of food loss and waste in the production of goods for human consumption represents a significant obstacle to the establishment of a sustainable food system. Fruit is a major food commodity that is disproportionately affected by high levels of food loss and waste (FLW) throughout the global food supply chain. In South Africa, 25% of all fruit produced is processed through techniques such as juicing, canning, and drying. These fruit processing activities are known for significant quantities of inedible fruit losses in the form of stems, pips, stones and peels. However, in depth quantification into the edible quantities lost during fruit processing activities in South Africa are limited. A reliable quantification methodology to account for edible fruit losses within the fruit processing stage of the food supply chain in South Africa is important to measure and monitor progress towards the United Nations Sustainable Development Goal Target 12.3. The aim of this study, therefore, was to establish a methodology for determining the magnitude of fruit losses, including the differentiation of edible and inedible losses, within the fruit processing sector of South Africa. The quantification of fruit losses was based on desktop study findings on the quantities and configuration of fruit processed in South Africa, estimates published in scientific literature and databases, and survey responses gathered in the present study. This study found that the total amount of fruit losses generated from the fruit processing stage in South Africa amounts to 44% of the total input weight of fruit sent for processing annually. This 44% loss is further split into 24% edible fruit losses and 20% inedible fruit losses. The findings from the present study can be used by decision makers within government, business and the fruit processing industry to better understand the definitional framework of food losses that are aligned with SDG Target 12.3, and to determine where the food loss hotspots are for further research to design and implement targeted prevention or reutilization strategies for food loss reduction in the fruit processing stage of the South African food supply chain.

Opsomming

Die voorkoms van voedselverlies en vermorsing in die produksie van goedere vir menslike gebruik verteenwoordig 'n beduidende struikelblok vir die vestiging van 'n volhoubare voedselstelsel. Vrugte is 'n groot voedselkommoditeit wat buite verhouding beïnvloed word deur hoë vlakke van voedselverlies en vermorsing dwarsdeur die wêreldwye voedselvoorsieningsketting. In Suid-Afrika word 25% van alle vrugte wat geproduseer word, verwerk deur tegnieke soos versapping, inmaak en verdrooging. Hierdie vrugteverwerkingsaktiwiteite is onderhewig aan aansienlike hoeveelhede oneetbare vrugteverliese in die vorm van stingels, pitte en skille. In diepte-kwantifisering van die eetbare hoeveelhede wat tydens vrugteverwerkingsaktiwiteite in Suid-Afrika verlore gaan, is egter beperk. 'n Betroubare kwantifiseringsmetodologie om die verliese van eetbare vrugte binne die vrugteverwerkingstadium van die voedselvoorsieningsketting in Suid-Afrika te verreken, is belangrik om vordering na die Verenigde Nasies se Volhoubare Ontwikkelingsdoelwit 12.3 te meet en te monitor. Die doel van hierdie studie is dus om 'n metodologie daar te stel vir die bepaling van die omvang van vrugteverliese, insluitend die differensiasie van eetbare en oneetbare verliese, binne die vrugteverwerkingsektor van Suid-Afrika. Die kwantifisering van vrugteverliese is gebaseer op lessenaarstudiebevindinge oor die hoeveelhede en samestelling van vrugte wat in Suid-Afrika verwerk is, skattings gepubliseer in wetenskaplike literatuur en databasisse, en opname-reaksies wat in die huidige studie ingesamel is. Hierdie studie het bevind dat die totale hoeveelheid vrugteverliese gegenereer vanaf die vrugteverwerkingstadium in Suid-Afrika 44% beloop van die totale insetgewig van vrugte wat jaarliks vir verwerking gestuur word. Hierdie 44% verlies word verder verdeel in 24% eetbare vrugte verliese en 20% oneetbare vrugte verliese. Die bevindinge van die huidige studie kan deur besluitnemers binne die regering, besigheid en die vrugteverwerkingsbedryf gebruik word om die definisieraamwerk van voedselverliese wat in lyn is met SDG-teiken 12.3 beter te verstaan, en om te bepaal waar die voedselverlies-brandpunte is vir verdere navorsing om geteikende voorkoming- of herbenuttingstrategieë te ontwerp en te implementeer vir voedselverliesvermindering in die vrugteverwerkingstadium van die Suid-Afrikaanse voedselvoorsieningsketting.

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I wish to express my sincerest appreciation to my primary supervisor, Prof Gunnar Sigge, who guided me through this research assignment. I would also like to thank my parents; for their unwavering love and support. Finally, I wish to thank my loving husband, Neil, and my two wonderful sons, Joubert and Joshua, for their unconditional support throughout my studies, and writing of my research assignment.

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Chapter 1 INTRODUCTION

Food losses and waste (FLW) is a major obstacle in the path of a sustainable food system. It compromises the social, financial and environmental foundation necessary to build upon for food and nutrition security for future societies (Foley *et al*., 2011; HLPE, 2014). With the world population set to reach 8 billion people in November 2022 (United Nations, 2022), the pressure to reduce FLW has become a top priority on the global agenda. Target 12.3 of the Sustainable Development Goals (SDG), accepted by the general assembly of the United Nations in 2015, is testament to this as its set goal is to decrease food losses along the production, post-harvest, manufacturing and distribution stages of the food supply chain and to halve the food waste accounted for per person in the retail and consumer level by 2030 (United Nations, 2015).

In literature there are multiple perspectives seeking to define FLW (Chaboud and Daviron, 2017; Chauhan *et al*., 2021). FLW can be understood and defined according to different criteria, each applied by researchers to reflect an underlining interest linking FLW with social, economic or environmental implications (Nicholes *et al*., 2019). Notably, FLW can be defined to stages within the food supply chain where it occurs, human edibility, quality (in terms of nutrition, appearance and length of preservation), nature of food use (whether FLW was planned or put to productive use) and finally according to the end destination where FLW is utilized further or discarded (Chauhan *et al*., 2021).

SDG Target 12.3 incorporates both edible food and its inherent inedible parts that leave the food supply chain and is tracked through two indicators linked to distinct stages within the supply chain (UNEP, 2021). The United Nations (UN) Food and Agriculture Organisation (FAO) monitors the food losses that accompany key food commodities within the upstream stages of the food supply chain, whereas the United Nations Environment Programme (UNEP) measures the total aggregated food waste at a consumer and retail level within a country (FAO, 2018; UNEP, 2021). As a champion of SDG Target 12.3, the South African Government is committed to create a favourable setting to enable role-players within the food supply chain to reduce FLW. The Consumer Goods Council of South Africa (CGCSA) in consultation with more than 400 stakeholders from government, industry, academia and civil society came together and joined in South Africa’s obligations to reduce FLW in the food supply chain (CGCSA, 2020). In September 2020, the ‘South African food loss and waste voluntary agreement’ was established which binds food processors, manufacturers and retailers to the country’s commitment to decrease FLW in order to accomplish SDG Target 12.3 (CGCSA, 2020).

Globally, fruit is one of the main food commodities that is associated with high amounts of FLW throughout the food supply chain (Campos *et al.,* 2020; FAO, 2020). In South Africa commercial fruit growers produce over 5.1 million tonnes of fruit per annum (Fruit SA, 2021). Whilst most of the fruit is sold fresh on the export market (64%) and local market (11%), approximately 25% is sent for processing (Fruit SA, 2021). The main processing activities that dominate the South

African fruit processing sector is juicing, canning and drying fruit (DALRRD, 2021). However, all these processing operations produce unavoidable residual solid matter that can be comprised out of pomace, skins, pips, stones and peels (Ben-Othman *et al*., 2020; Campos *et al*., 2020).

In depth research into food losses in the fruit processing stage of the food supply chain in South Africa is limited. Most of the existing studies highlight the environmental implications of fruit processing FLW through a waste management perspective, that is aimed at establishing the FLW valorization and utilization potential of FLW streams within the fruit processing industry (Khan *et al*., 2015; Oelofse and Muswema, 2018b; Manhongo *et al.,* 2022). Quantifying FLW from only a waste management perspective will amount to significant amounts of losses as all the inherent inedible parts of fruit are grouped together with edible quantities of fruit that is lost during processing activities. Thus, for fruit processing entities to adhere to SDG Target 12.3, and reduce food losses during fruit processing, will be a difficult task as reducing the amount of inedible fruit quantities during processing can be limited (Champions 12.3, 2017). However, if edible and inedible losses can be quantified separately, the SDG Target 12.3 only needs to apply to the edible quantities of the fruit losses, although it is still imperative that steps need to be in place that aim to reduce or reutilize the amount of inedible parts (Champions 12.3, 2017). Another factor to consider in gaining a better perspective on effectively quantifying food losses within the fruit processing sector is to take in consideration that in addition to fruit processing losses, avoidable losses due to human behaviour, such as planning, management choices or negligence is inevitable and occurs at each processing facility (Beretta *et al*., 2013).

In South Africa the quantities of edible food losses within the fruit processing stages are unknown. Hence, the absence of comprehensive knowledge on the quantities of food losses within the fruit processing sector in South Africa makes it challenging to establish a baseline and to measure progress in line with SDG Target 12.3. Quantifying the configuration of total food losses can also play an instrumental part in providing a foundation for more research into the societal, financial, and environmental impacts of fruit losses in the fruit processing sector (Xue *et al*., 2017).

In conclusion, the quantification of losses in the fruit processing phase of the food supply chain is instrumental to: i) create awareness amongst key role players as to where to prioritise resources to minimise and mitigate losses; ii) to identify food loss hotspots; iii) to establish an industrywide baseline to measure and monitor progress against targets and; iv) to providing insights into unrecognised opportunities and strategies to valorize or reutilize food losses; (Caldeira *et al*., 2019; Xue *et al*., 2017; Corrado *et al*., 2019).

Chapter 2 AIMS AND OBJECTIVES

The aim of this research assignment is to establish a systematic approach to effectively quantify food losses generated within the fruit processing stage of the food supply chain in South Africa, to measure food losses in accordance with SDG sub-indicator 12.3.1a

Three main objectives are:

1. To provide in detail the flow and configuration of the quantities of 18 fruit types processed on average per year in South Africa.
2. To determine the total fruit losses and specific individual fruit losses of 18 fruit types associated with the fruit processing methods under investigation, using indirect and direct data collection methods.
3. To determine the quantities of edible and the inherent inedible quantities of food losses generated by the 18 fruit types processed using the methods under investigation.

Chapter 3 LITERATURE REVIEW

3.1 Overview of Sustainable Development Goal (SDG) Target 12.3

In September 2015, at the United Nations General Assembly, SDG 12 was formally adopted by South Africa and 192 other countries as part of 17 Sustainable Development Goals (StatsSA, 2019). SDG 12 was established to pursue and safeguard sustainable production and consumption activities throughout the food supply chain (FAO, 2022a). The third target under this goal (Target 12.3) calls for the reduction of food losses along the production, post-harvest, manufacturing and distribution stages of the supply chain, and a reduction of 50% per capita of global food waste within the retail and consumer stages (FAO, 2022a). As this third target consists of two components in the form of 'food losses' and 'food waste', two separate indicators have been developed, namely sub-indicator 12.3.1a and sub-indicator 12.3.1b, respectively. The FAO, by means of the Food Loss Index (FLI), became the custodian to measure food losses and the UNEP became the custodian of the Food Waste Index (FWI) to measure food waste (FAO, 2018; UNEP, 2021), as seen below in Figure 3.1.

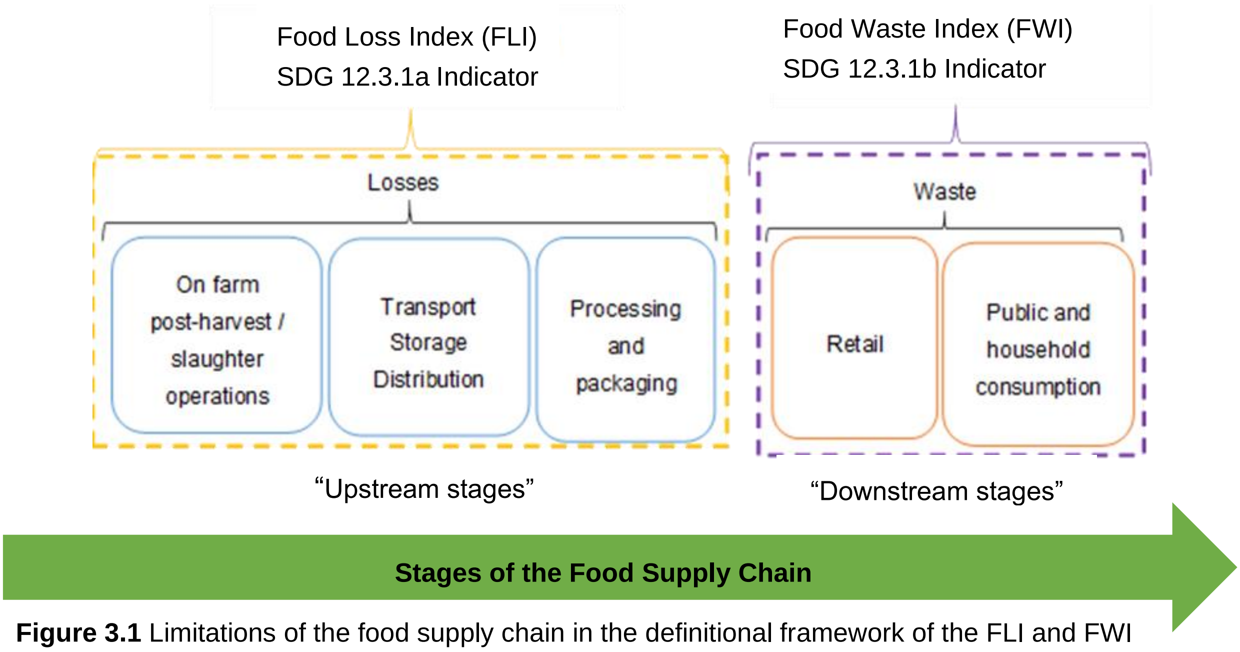

Figure 3.1 Limitations of the food supply chain in the definitional framework of the FLI and FWI (Adapted from the FLI: FAO, 2018)

The focus of the FLI is to measure losses within a set boundary of the on farm production stage up until (but not including) the retail stage of the food supply chain, and it measures (in percentage by weight) the losses of a group of ten commodities by country in comparison to a baseline period (FAO, 2022a). Unlike the FLI, the FWI is responsible for measuring all food waste in the retail and consumption stages and not only the waste connected with specific food commodities in the downstream stages of the food supply chain (UNEP, 2021). The FLI and the FWI do however overlap in the food manufacturing stage where food losses within its specific commodity group is measured by the FLI while manufacturing waste with a mixture of food commodities is captured as food waste by the FWI (UNEP, 2021).

To clearly observe and measure the impact of policy interventions and investments aimed at increasing the effectiveness of the food supply chain, it is essential to collect data for all the stages of the food supply chain to assist countries to design programs that will improve the operations and productivity of their food supply system (FAO, 2022a). Globally, the amount of food lost is estimated at 13.3%, with no real movement in values since 2016 (FAO, 2022b). Sub-Saharan Africa is responsible for the highest quantities of food being reported as lost at 21.4% (FAO, 2022b). Recent figures from the 2021 FWI show that the retail and final consumption stages of the food supply chain is where 17% of total global food is wasted (UNEP, 2021). However, FLW data in South Africa is scarce, as South Africa only has a 15.4% indicator coverage for SDG Target 12 and does not have national data available on Target 12.3 (Goal Tracker SA, 2022).

3.2 Defining Food Loss and Waste

Understanding what FLW entails in the food supply chain is rather complex as the definition of FLW differs substantially in literature (Xue *et al*., 2017; Chaboud and Daviron, 2017; Chauhan *et al*., 2021). Some of the key elements within the definitional framework of FLW that is universally similar is the timing within the food supply chain from when food can be considered as FLW and the scope, as only food commodities originally intended for human consumption are taken into account (Chaboud and Daviron, 2017). Other aspects such as terminology adopted, dimensions of edibility used, intention of FLW generation considered, perspectives of FLW by different stakeholders and the impact of end destinations on the concept of FLW all differ fundamentally within the different definitional frameworks of FLW (Chaboud and Daviron, 2017; Chauhan *et al.*, 2021). Thus, when existing data is extrapolated from literature, the differences within the definitional frameworks limit the comparability of results and their usefulness in attempting to establish a baseline or measure progress towards SDG Target 12.3 (Corrado *et al*., 2019; Teigiserova *et al*., 2019).

According to the FAO, 'food loss' is the decrease in quantity (mass) or quality attributes (reduction of nutritional value, economic value, aesthetical standards or/and food safety) of edible food intended for human consumption that is removed from the production stage up until the distribution stage of the food supply chain and ultimately not consumed by people (FAO, 2015). Quantitative food loss refers to the physical removal of edible food due to the intrinsic institutional and legal frameworks, such as food grading and sorting for aesthetical compliance, and food industry safety regulations, accompanying the food commodity from the production stage up until the distribution stage of the food supply chain (FAO, 2014). It does not however include the reduction of mass attributed to the removal of the inherent inedible parts, food processing activities such as drying or heating where no losses are physically gathered, or food that is intentionally produced for other uses, such as animal feed or biofuel (FAO, 2014; FAO, 2019). Within the FAO definitional framework 'food waste' is a dimension of food loss and refers to situations where edible food, fit for human consumption is removed from the retail or final consumption stages (restaurants, homes) of the food supply chain because of human behaviour such as food spoilage or expiry of sell by dates caused by poor management or neglect (FAO, 2014). The firm emphasis on the edibility of food intended for human consumption reflects the intent of the FAO to position its definitional framework of 'food loss' and 'food waste' within a food security viewpoint as edible food losses equate to reduced amounts of food available for human consumption within the food supply chain (FAO, 2014).

A clear limiting factor within the FLW definitional framework of the FAO is that food losses are viewed as unavoidable within the upstream stages of the food supply chain whereas wasteful behaviour can occur in the upstream stages just as other reasons for food losses can occur in downstream stages (Beretta *et al.,* 2013).

The European Union's Food Use for Social Innovation by Optimising Waste Prevention Strategies project (FUSIONS) proposes an alternative definition for FLW. FUSIONS refer to food waste as food which is intended for human consumption, and its inherent inedible parts, that is removed from the food supply chain (Tostivint *et al*., 2016). However, when food waste leaves the food supply chain to be further utilized or recovered (according to set criteria) it is not classified as food waste (Tostivint *et al*., 2016). Unlike the FAO, the primary focus of FUSIONS's definitional framework of FLW falls on resource efficiency within the food supply chain (Hartikainen *et al*., 2018). This definition is also in line with the principals of the Food Loss and Waste Standard, an internationally accepted standard which accounts for and reports on food and/or associated inedible parts removed from the food supply chain (Tostivint *et al*., 2016).

Careful consideration should be given when deciding on a definitional framework and its system boundaries when investigating FLW in the food supply chain, as it will directly influence the outcomes and conclusions. Hartikainen *et al.* (2018) established that FLW quantified from a food security perspective resulted in a three times higher quantification value of FLW than a definitional framework focussed on quantifying FLW from a resource efficiency perspective.

Given uncertainties around achieving SDG Target 12.3, the Champions 12.3 network – an alliance of industry leaders, government officials and public and international organisations aimed at fast-tracking progress towards SDG Target 12.3 – released a 2017 publication that aimed to provide guidance on what should be considered the best approach in the interpretation of SDG Target 12.3 (Champions 12.3, 2017). It reasons that FLW should apply to both food intended for human consumption and its inherent inedible parts which can be further utilized, because Target 12.3 falls under the umbrella of SDG Target 12 which strives for sustainable consumption and production throughout the food supply chain and not SDG Target 2 that strives to end hunger (Champions 12.3, 2017).

Thus, in addition to the FAO food loss definition, the FAO adopted an operational definitional framework in its 'Food Loss Index' to better align in terms of consistency and measurability with other FLW definitions (FAO, 2018). The FAO operational framework defines food losses as "all human-edible commodity quantities that completely exit the food supply chain and do not re-enter in any other utilization, up to the retail level" (FAO, 2018). The term losses include "the commodity as a whole with its non-edible parts" (FAO, 2018). Within the FAO operational definitional framework, the concept of food losses has the same set boundaries within the supply chain as the FAO (conceptual) definitional framework but differs where losses now exclude qualitative losses and include the inedible parts of food commodities (FAO, 2018). In the same drive to better measure and account for food waste, the UNEP aligned the FWI to define the concept of 'food waste' as all human edible food with its associated inedible parts removed from the retail, food service and household stages in the food supply chain (UNEP, 2021). These two definitions by the FAO and the UNEP for 'food loss' and 'food waste' form the proposed indicators to measure and account for global food losses and waste, in line with SDG Target 12.3.

3.3 Defining the dimension of edibility

From the FAO operational framework, FLW can be either classified as edible or as inedible. Edible refers to the part of food that "a population of specific cultural or economic group traditionally consume" (FAO, 2018), or food items that can be ingested without causing harm (Nicholes *et al*., 2019). Inedible refers to the inherent parts of food that "in a particular food supply chain, are not intended (culturally of physically) to be consumed by humans" (WRI, 2016). Understanding and reporting on the ratio between edible and inedible parts of food is not a requirement according to the two indicators of SDG Target 12.3, as the target to reduce food losses throughout the upstream stages of the supply chain and to halve consumer food waste, include food's inedible parts. That is, they focus on total FLW, regardless of food's edibility (FAO, 2018; UNEP, 2021). However, understanding the composition of food can give insights on the expected quantities of FLW and the locations within the food supply chain where FLW is most likely to occur. Better insights on this inherent problem will help in putting together better preventative strategies or policy interventions to either reduce edible FLW or to find sustainable, circular food system solutions for inedible FLW (UNEP, 2021).

Champions 12.3 makes the point that if government institutions or business establishments can measure and report food losses and the inherent inedible parts separately, then they should be able to apply the SDG Target 12.3 reduction targets only to the edible food portion – although they stress that there should still be effort in reducing the amount of inedible parts (Champions 12.3, 2017). This adaptability acknowledges that for some food commodities and stages within the food supply chain a substantial amount of FLW may be associated with inedible parts (Champions 12.3, 2017).

In a study by De Laurentiis *et al*. (2018), the avoidable and unavoidable waste generated by fresh fruit and vegetables in EU households was quantified to formulate prevention strategies and for waste management purposes. The methodology used for quantification was based on estimations of the unavoidable waste intensity and the avoidable waste intensity of fruits and vegetables derived from National Nutrient Databases (De Laurentiis *et al*., 2018). The study defined unavoidable food waste as “food waste arising from preparation or consumption that has never been edible under normal circumstances” and avoidable food waste as edible food that has been discarded (De Laurentiis *et al*., 2018). The generation of unavoidable waste is thus directly connected to the inedible portions of food, while avoidable waste is due to behavioural choices by the consumer (De Laurentiis *et al*., 2018).

Although the potential for using the De Laurentiis *et al.* (2018) modelling approach is valuable to quantify food waste of unprocessed single commodity foods within the retail and consumption stages of the food supply chain, unavoidable losses can inevitably be attributed to more factors than only the inedible fractions of food in the food supply chain. Other factors that can directly impact unavoidable food losses are food grading or sorting, harvesting methods applied, microbiological or chemical contamination, storage complications, power blackouts, method of processing, equipment defects, transport and weather conditions (Beretta *et al*., 2013; Raak *et al*., 2017).

Hartikainen *et al*. (2018), established a framework to define and measure edible food losses in the primary production stage by utilizing data from country specific case studies and estimates published in literature. Unlike the study by De Laurentiis *et al*. (2018), the edible portion of food was calculated by a conversion factor that took into consideration processing losses that is inherent to the food commodity (Hartikainen *et al.,* 2018). One can argue that this methodology offers a better representation of food losses as more (unavoidable) factors other than only inedible parts are accounted for.

3.4 Overview of FLW measurement

There are numerous methods available in literature to measure FLW which can be categorised into two groups. Firstly, direct measurement from actual data due to first-hand access to FLW quantities and secondly, inference by calculation derived from secondary data sources (Xue *et al*., 2017). The following methods are commonly used to directly measure FLW:

i. Direct weighing: Involves using a weighing device, such as a scale, to measure the quantity of FLW (FLW Protocol, 2016a). An advantage of weighing is the set unit of weight that is displayed by a weighing device, where no other conversions are necessary that can bring an element of inaccuracy (FLW Protocol, 2016a). A major disadvantage however is the cost of weighing equipment and the limitation of moving it if FLW weight must be taken at multiple locations (FLW Protocol, 2016a). Areas identified in literature where direct weighing is used as a quantification method include the measurement of food waste in households (Ramukhwatho, 2016), school cafeterias (Derqui *et a*l., 2017), restaurants (Wang *et al*., 2017), hospitals (Dias-Ferreira *et al*., 2015) and the retail sector (Broekmeulen and Donselaar, 2019).

ii. Counting: Involves the use of visual observation, scanner data and visual scales to count the number of items that contain FLW and using the sum of the calculated number to determine the weight (FLW Protocol, 2016b). Counting may result in highly accurate data at a low cost, hence the focus is not to quantify multiple items or a variety of sizes as this will leave the door open for more assumptions leading to inaccuracies in FLW estimates (FLW Protocol, 2016b).

iii. Assessing volume: Involves measuring the volume or space occupied by FLW where an element of liquid is involved and converting the values to a weight using density factors (FLW Protocol, 2016c).

iv. Waste composition analysis: Involves the categorisation of FLW by physically separating it from the waste flow before measuring the amount (FLW Protocol, 2016d). Although this method is very time consuming and involves complex logistics to accurately capture and quantify FLW without other materials and packaging, a lot of insights can be gained from the compositional analysis of the food disposed (Corrado *et al*., 2019). As was the case with a study by Oelofse *et al.,* (2018a) where municipal waste was categorised and weighed to gain better insights into the type and quantities of food wasted by households.

v. Records: Involves data that is routinely collected and documented such as processing yields, warehouse inventory information or point of sale data (FLW Protocol, 2016e). Even though the data is not collected specifically for FLW quantification it is valuable source of data to map the flow of FLW within an entity, especially if the method used to generate the data is clear (FLW Protocol, 2016e).

vi. Diaries: Involves the gathering of data on the amounts and types of FLW generated over a set time in a daily log (Xue *et al*., 2017; FLW Protocol, 2016f). This method is sometimes used together with weighting scales to account for household food waste (Chakona and Shackleton, 2017; Xue *et al*., 2017).

vii. Surveys: Involves the collection of information on FLW types and quantities in a cost-effective way from participating individuals (FLW Protocol, 2016g). In tandem, researchers can also gain insights into people's perceptions, attitudes or self-reported behaviours regarding reasons for why or how FLW occurs (Xue *et al*., 2017).

Methods using indirect measurements compiled from secondary data sources include:

i. Mass/Food balance: Involves the use of a food balance sheet to calculate FLW by measuring inputs, outputs and changes in stock levels throughout the stages of the food supply chain (Xue *et al*., 2017). The much-cited study by Gustavsson *et al*. (FAO, 2011) that estimated one third of the world's food is lost or wasted annually made use of food balance sheets from FAOSTAT to calculate FLW estimates.

ii. Models: Involves the use of mathematical approaches to calculate FLW based on intentional or causal factors that directly impact FLW generation (FLW Protocol, 2016h).

iii. Proxy or literature data: Involves the use of data estimations from literature or other entities where direct measurement of FLW is not feasible (FLW Protocol, 2016i; Xue *et al*., 2017).

From all the measurement options available to researchers, the use of surveys as a direct measurement and modelling as an indirect measurement are by far the most popular methods used to quantify FLW in recent years (Kafa and Jaegler, 2021). Studies mainly focused on the measurement of FLW within a specific stage of the food supply chain tend to rely more on primary data whereas studies targeting FLW measurement within a particular geographical area or across different countries rely more on secondary data sources (Chauhan *et al*., 2021). However, to collect primary data from industry can be extremely challenging as companies view their FLW data as commercially sensitive and are not forthcoming in sharing data (Corrado *et al*., 2019). Another limitation in collecting primary data is that the terminology used in industry does not always coincide with definitions used by academic or the legislative framework to quantify FLW (Corrado *et al*., 2019).

3.5 General information about the fruit processing sector in South Africa

South Africa's varied climatic conditions and topography allows for multiple different agricultural regions which enables the country to grow a broad variety of fruits. South Africa is one of the main global producers of citrus and produced an estimated 3 million tonnes in 2021 (CGA, 2022). The rest of the main fruit types cultivated include pome fruit, stone fruit, sub-tropical fruits and table grapes (DALRRD, 2021).

Fruit production has shown continuous growth in recent years driven mainly by the high demand for South African fruit in the export market. Population growth, changing dietary transitions and urbanisation within South Africa are also driving a higher demand for fruit, especially processed products that can be easily stored and transported (World Bank, 2019). According to Fruit SA (2021), 25% of fruit produced in South Africa is sent for processing. Fruit processing is a key sector in South Africa as it is very labour-intensive and has the potential to spur on value added growth, create jobs and support the economy (Van Lin *et al*., 2018). Processed fruit products also impact food security in a positive way by extending the shelf life and optimising the quality of fruit (Augustin *et al*., 2016). As shown in Table 3.1, fruit can be processed into a variety of processed products utilizing different processing methods.

The processing level of fruit can be separated into three parts (Dube *et al*., 2018):

- Primary processors: convert fruit into dried fruit, frozen fruit, canned fruit, fruit juice, fruit puree and concentrates.
- Secondary processors or "blenders": processed fruit from primary processors is processed further and blended with various additional additives (sugar, flavours, acidity regulators, thickeners, etc.) and converted into jams, jellies, preserves or fruit juices, fruit nectars and fruit drink blends.
- Bottlers/packers: the final product is packed and distributed to the retail sector.

To ensure a constant supply of fruit, and to avert competition with the export and local fresh fruit market, fruit processors are frequently vertically integrated into farming operations (Dube *et al*., 2018). With very high capital investments, skilled labour and advanced infrastructure needed to perform fruit processing operations, the observed trend in recent years has been for small processors to consolidate with large processors rather than setting up new processing plants (Dube *et al*., 2018).

Table 3.1 Summary of possible processing destinations of fruit produced in South Africa

Raw Fruit	Processing	Preservation Method
Peaches, apricots, guavas, pineapples, apples, pears, berries and cherries	Canned fruit	Heat treatment, with optional synergetic action of sugar or juice concentrate to reduce water activity
Apricots, peaches, berries, plums, figs and cherries	Jam	Heat treatment, with optional synergetic action of sugar or juice concentrate to reduce water activity
Citrus fruits	Marmalade	Heat treatment, with optional synergetic action of sugar or juice concentrate to reduce water activity
Variety of fruits	Juices and pulps	Thermal treatment
Variety of fruits	Fruit concentrates	Thermal treatment and evaporation to reduce water activity
Variety of fruits	Confectionary	Act of sugar as a humectant and the reduction of water activity
Variety of fruits	Placed in alcohol	Reduction of water activity
Variety of fruits	Dried	Drying, reduction in water activity
Variety of fruits	Frozen	Freezing

Adapted from Santonja *et al*., 2019.

3.6 Overview of applied fruit processing methods

Information on the configuration of fruit processed in South Africa is scarce, however fruit producer associations, fruit processing associations and government departments provide information on the ratios of processing methods used per fruit variety. The following is known about the predominant fruit types and the accompanying fruit processing methods utilized to process fruit in South Africa.

Deciduous fruit

Deciduous fruit is primarily produced in South Africa's Western and Eastern Cape provinces and include apples, pears, table grapes, peaches, nectarines, plums, apricots and cherries (DALRRD, 2021). For the past five seasons deciduous fruit sent for processing was predominantly sent to be processed into juice, with apricots and peaches being the only exception as they are mostly processed into canned fruit products (DALRRD, 2021). According to the Canning Fruit Producers Association (CFPA), 20 467 tonnes of apricots (59% of apricots sent for processing), 81 400 tonnes of peaches (68% of peaches sent for processing) and 37 672 tonnes of pears (21% of pears sent for processing) where canned in the 2020/2021 season (Die Krat, 2021; Hortgro, 2021a; Hortgro, 2021b). The quantities of deciduous fruit from the 2020/2021 season that was sent for processing as dried fruit consists of 1 610 tonnes apples, 6 888 tonnes pears, 6 325 tonnes apricots, 12 590 tonnes peaches and 1 107 tonnes plums, representing 0.4%, 4%, 18%, 11% and 56% respectively of the total fruit per type of fruit sent for processing (Hortgro, 2021a; Hortgro, 2021b).

Subtropical fruit

Most of the subtropical fruit produced in South Africa are from Limpopo, Mpumalanga and KwaZulu-Natal (DALRRD, 2021). Granadillas and guavas are however also produced in the Western Cape, whereas pineapples are predominantly produced in the Eastern Cape (DALRRD, 2021). Table 2 below presents the available data on the configuration of subtropical fruit sent for processing in South Africa.

Table 3.2 The configuration of subtropical fruit sent for processing in South Africa

Subtropical fruit	**Configuration of fruit sent for processing in 2021**	**Reference**
Avocado	4 745 tonnes sent for processing avocado oil (35%) 8 683 tonnes sent for processing guacamole (65%)	SAAGA, 2022
Mango	14 692 tonnes sent for processing dried mango (31%) 25 000 tonnes sent for processing atchar (53%) 7 338 tonnes sent for juice processing (16%)	SAMGA, 2022
Guava	62% of guavas produced is sent for juice processing 12% of guavas produced is sent for canning 2% of guavas produced is sent to be dried	Guava Producers Association, 2022

Citrus fruit

Citrus fruit is primarily produced in the Western Cape, Eastern Cape, Mpumalanga, Limpopo and KwaZulu-Natal provinces of South Africa (DALRRD, 2021). Most of the citrus fruit sent for processing is sent to be juiced into fresh, frozen or concentrated juice products (DALRRD, 2020).

3.6.1 Juicing, pulping and concentrates

The first stage in processing fruit into juice or concentrate is when raw fruit enters the fruit processing site to be sorted and graded for appropriate ripeness and size and washed in order to remove any unwanted soil residues, insects, leaves or mouldy deteriorated fruit (Sinha *et al*. 2012).

The next stage depends on the type of fruit being processed. Citrus fruit is rolled over oil extraction equipment where small incisions are made on the surface of the outer layer of the citrus peels to break open the oil sacks in order for the oil to be washed off and further processed into citrus oils (Santonja *et al*., 2019). This processing stage can however also occur when the peels are further processed after juice extraction, but as the peels contain volatile substances it can greatly affect the quality of the juice if not removed before juice extraction (Rajauria and Tiwari, 2018). It depends on the prerogative of the fruit processor if citrus oils are to be extracted as this is a side flow processing step. For stone fruit and berries, stems are removed before the washing step as they can spoil the colour and give unfavourable qualities to the juice (Rajauria and Tiwari, 2018). Fruit parts that include cores, pits, or pips are removed after the washing stage (Santonja *et al*., 2019).

At the next stage, the fruit passes through a mechanical chopping or crushing process to extract as much juice or pulp from the solid fruit flesh particles as possible (Sinha *et al*., 2012). Various parts of blades, crushers and cutting machines are used to remove the unwanted parts of the fruit such as peels, skin and seeds (Rajauria and Tiwari, 2018). During this stage several other methods can also be used on fruit to release the maximum amount of juice such as heat treatment, enzymatic procedures, vibration, ultrasonic waves, electro-plasmolytic, and ion-radiation procedures, with the heat treatment and enzymatic procedures having been proven to increase juice yield by up to 5-10% (Sinha *et al*., 2012).

The following stage involves the extraction of juice by applying pressure and pressing the fruit to split into two phases, fruit flesh in the solid phase and the juice forming the liquid phase (Sinha *et al.,* 2012). This is an important stage in fruit juice processing as this is where the yield, or percentage juice extracted compared to the weight of the fruit during receiving is calculated (Sinha *et al*., 2012). Depending on whether a cloudy or clear juice is required, the next step entails the clarification of juice by passing the juice through a variety of sieve mesh sizes and centrifugation to suspend the solids present in the juice (Rajauria and Tiwari, 2018). Using enzymatic extraction on guava and orange juice has shown a significant improvement on the clarity (Chopda and Barrett, 2001; Diaz *et al*., 2012). Other methods to clarify juice include filtration, coagulation or precipitation-based methods in order to partially or entirely remove particles to avoid turbidity and enhance sensory attributes of the juice (Rajauria and Tiwari, 2017).

Finally, after the clarifying stage the juice is preserved by pasteurization and packed in sterilized bottles or in aseptic conditions in preformed cartons (Sinha *et al*., 2012). If the goal is to manufacture fruit concentrates that have much better transportation, shelf life and storage benefits, juice concentration through reverse osmosis, evaporation and freeze concentration can be implemented to reduce water activity with minimal losses to sensory traits (Sinha *et al*., 2012). With puree processing a different method is followed. The first stage regarding the receiving of fruit and the mechanical chopping stage is in line with juicing, but fruit goes through a blanching stage where the chopped fruit pieces are preheated to soften the texture of the fruit and to inactivate enzymes in the fruit that can damage the texture and visual appeal of the fruit later in the processing stages (Sinha *et al*., 2012). The next step is where the fruit pieces are forced through a sieve to separate any skin and seed particles from the fruit puree (Sinha *et al*., 2012). Fruit puree is then further homogenized to slow down the settlement of particles and to ensure a homogenous, smooth puree texture (Sinha *et al*., 2012). In the last phase the fruit puree is preserved through a heat treatment and filled into aseptic bags under aseptic conditions (Sinha *et al*., 2012).

3.6.2 Canning

For canning the quality of the raw fruit needs to be at the right level of ripeness in order to produce high quality canned fruit (Sinha *et al*., 2012). As fruit is produced seasonably the processing per fruit variety for canning needs delicate planning to ensure that incoming fruit is processed as soon as possible after delivery for optimal quality (Sinha *et al*., 2012). Upon receiving fruit, the fruit enters a sorting and washing phase to remove dirt and mould spores before being graded, trimmed, cored and peeled (Santonja *et al*., 2019). Various methods are available to peel fruit and depending on the fruit type a method is chosen to ensure minimal losses. Common peeling methods include caustic peeling, steam peeling, abrasion peeling, mechanical peeling and flame peeling (Santonja *et al*., 2019). After the peeling process, fruit is blanched to inactivate enzymes negatively affecting the flavour and texture of the fruit (Sinha *et al*., 2012). The blanching process also stops respiratory gases from forming in order to increase the vacuum within the can and preventing oxidation that will affect the quality of the fruit and cause corrosion on the inside of the can (Sinha *et al*. 2012). Fruit may also be immersed in tanks with a brine or ascorbic acid solution to preserve the colour of the fruit (Santonja *et al*., 2019). Next, fruit is sliced or diced mechanically into the desired portions needed for the final product. The fruit is filled into cans with a syrup or juice solution at set temperatures to ensure a uniform headspace for each container (Sinha *et al*., 2012). Trapped gasses and air are removed in the next step known as exhaustion which alleviates the build-up of pressure and oxidation in the containers (Sinha *et al*., 2012). The final phase is to seal the container as soon as possible, apply heat treatment by means of sterilisation and cooling to rapidly reduce the internal high temperature of the container to limit sensory deterioration (Santonja *et al*., 2019).

3.6.3 Drying

Drying fruit is one of the oldest preservation methods utilized. By subjecting fruit to a drying process, either by the sun or by means of a mechanical method where fruit is transported through drying tunnels, the water content of fruit is significantly reduced (Santonja *et al*., 2019). Low water activity in dried fruit stops microorganisms and enzymes from activating fruit spoiling mechanisms (Amit *et al*., 2017). The fruit drying process consist of receiving, sorting, grading, washing, trimming, coring, peeling (depending on the fruit type), drying and packing stages (Santonja *et al*., 2019). Just after the washing or peeling stage fruit is sulphated or dipped in a potassium carbonate solution to soften the fruits texture and to increase the moisture losses during drying (Santonja *et al*., 2019).

3.7 Fruit processing losses and their possible applications

Reducing and reutilizing fruit losses can positively impact economic growth, job creation and reduce environmental and social costs associated with waste management activities in South Africa (DST, 2014). Even small savings or increases in the monetary value of products after food loss quantities are reduced or reutilized can bring forth a financial advantage for food processors, on condition that food supply chains make adjustments and work towards a circular bioeconomy (Garcia-Garcia *et al*., 2019). The decision process of each processing or manufacturing facility will be influenced by several factors such as new equipment investment costs, employee competence, potential returns on investment, the profitability of fruit loss reduction and/or reutilization, consumer acceptance, food safety and regulatory protocols (Ganesh *et al*., 2022).
Depending on the processing methods utilized, solid fruit losses can be in the form of pomace, peels, cores, stems, pulp and seeds. Reutilizing fruit losses into new food ingredients or products can be challenging as most of the fruit losses that remain after fruit processing, is highly perishable and fermentable (Campos *et al*., 2020). However, fruit losses that are further processed may be utilized as natural additives to increase the quality and nutritional profile of existing or new food products (Majerska et al., 2019). Popular processing methods used to make ingredients from fruit residue include drying and dehydration of fruit losses to make microbiologically food safe powders and flours (Larrosa and Otero, 2021). Table 3.3 provides an overview of potential applications of fruit losses towards new value-added products.

Table 3.3 Overview of potential applications of fruit losses towards new value-added products

Fruit source	**Type of losses**	**Value-added product in the food industry**	**References**
Apple	Pomace	Fibre source in baked food products, meat products and dairy yoghurts.	Coman *et al*., 2019; Campos *et al*., 2020
	Pectin	Thickening or gelling agent and stabiliser in food and beverage products.	
Avocado	Dried peels	Antioxidant in beverages and in meat products.	Coman *et al*., 2019
	Seed	Seed starch to increase fibre content or improve textural properties of food. It can also be used in the development of biodegradable polymers for food or medicine packaging.	
Banana	Peel	Peel starch to increase fibre content of bread.	Coman *et al*., 2019
Citrus	Fibre	Source of 'heat and pH stable' fibre incorporated into meat, dairy and baked products.	Coman *et al*., 2019; Campos *et al*., 2020
	Pectin	Used as an emulsifier, stabiliser or thickener in processed foods and beverages.	
	Essential oils	Natural citrus aroma for food and beverage applications. Natural antimicrobial to use in food products.	
Mango	Peel and seed kernel powders	Increase nutraceutical properties in baked and pasta food products. Edible films for food packaging.	Coman *et al*., 2019; Campos *et al*., 2020
	Kernel oil	Nutraceutical additive to food	
	Peel fibre	Peel flours to use food applications as a source of fibre.	
Pineapple	Fibre	Stem and core flour to use food applications as a source of fibre.	Campos *et al*., 2020
Plum	Pomace extracts	Prevents lipid oxidation, extends the shelf life and improve the taste and appearance of meat products	Majerska *et al*., 2019

In recent years, the concept of using bioactive substances extracted from fruit residues has become so popular within the food science and technology domain that it has given rise to a new scientific field called "bio-residues valorization" (Martins and Ferreira, 2017). Different names in published papers refers to these products as "value-added surplus products", "waste-to-value products", "food from by-products" and "upcycled ingredients or foods" (Grasso and Asioli, 2020; Coderoni and Perito, 2021).

According to Ecovia Intelligence, an expert research, training and consulting company that concentrate on global ethical product industries, upcycled foods is becoming a global trend as consumers are becoming more aware of the environmental and economic impacts of food loss and food waste (Ecovia Intelligence, 2022). More and more corporate food manufacturers such as Mondelez Foods, Nestle, Del Monte, Barry Callebaut and Dole are investing in upcycled products as they see reutilizing FLW as a popular viable solution to achieve their sustainability goals (Ecovia Intelligence, 2022). In the past year, Nestle and the international chocolate company, Barry Callebaut launched chocolate made with upcycled cocoa fruit which would otherwise be wasted in chocolate production (Nestle, 2021; Ecovia Intelligence, 2022). Barry Callebaut's chocolate, Cabosse Naturals, received the Sustainable Ingredient award at the 2021 Sustainable Food Awards for their innovative new product (Ecovia Intelligence, 2022).

3.8 Concluding remarks

South Africa produces a unique composition of fruit types, with large quantities sent for processing each year. Each fruit type processed, as well as the processing method utilized contribute different ratios of fruit losses that can be further split into edible and inherent inedible food losses. For the fruit processing stage of the food supply chain in South Africa to be fully aligned with the SDG Target 12.3, the composition of fruit processing losses is essential to effectively quantify food losses. However, insights and accurate estimates on the unique composition of South Africa's fruit processing losses are limited. Without a detailed compilation of the quantities of fruit losses for each fruit type processed there will not be sufficient data to fill the gaps when modelling fruit loss flows for the fruit processing stage of the food supply chain in South Africa. Accurate quantification of fruit losses during South African fruit processing is crucial to prevent overrepresentation of total losses, including inedible waste. Proper quantification, based on edibility, is essential to accurately reflect actual food losses in the fruit processing stage. Acknowledging that the flow of direct data from fruit processing facilities is limited, as it is not feasible to gain full access into the fruit loss quantities of each fruit processing facility in South Africa, another approach is needed to acquire quantitative data that is representative of the food loss flows in South Africa. Establishing a systemized approach, using indirect and direct data gathering methods could help fill the data gaps on the unique composition and quantities of fruit sent to be processed annually in South Africa and the associated food losses generated. This data could subsequently be aligned with the FAO's FLI requirements to establish a food loss baseline for the fruit processing sector in South Africa against which progress towards SDG Target 12.3 could be measured.

Chapter 4: METHODOLOGY

4.1 Definition used

The definitions used in this paper are in line with the FAO SDG Target 12.3.1 indicator. Food losses are firstly quantified within the operational definitional framework and then subsequently according to the conceptual definitional framework as set out by the FAO FLI in Figure 4.1. In the FLI operational definitional framework 'food losses' is defined as all human edible commodities quantified in mass, (including its inherent inedible parts) that is removed from the food supply chain, and do not re-enter the food supply chain under any other utilization up to the retail level (FAO, 2018).The FLI conceptual framework quantifies the flow of 'food losses' further into 'edible' and 'inherent inedible' parts.

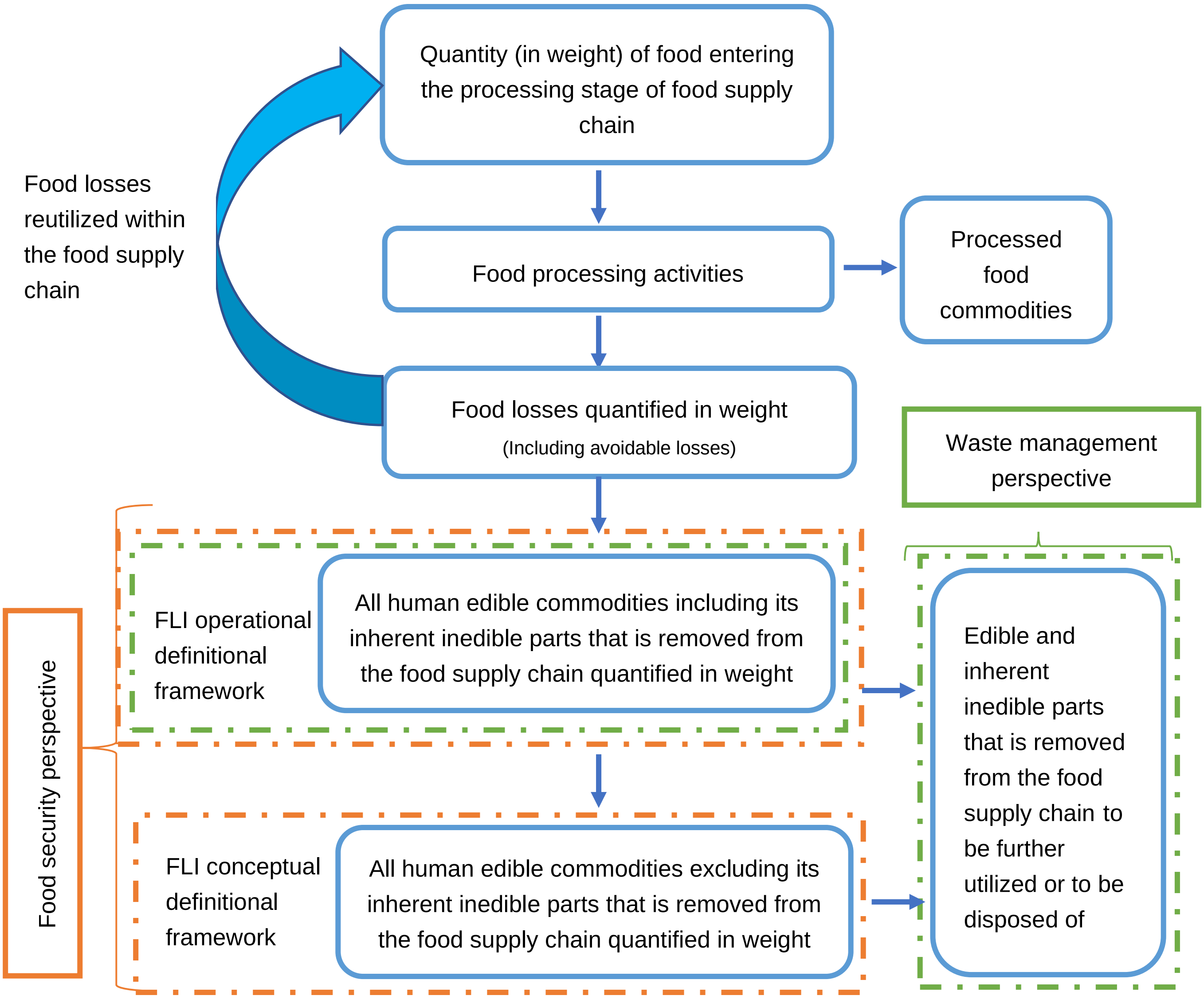

Figure 4.1 Overview of definitional framework used in this study

Within the context of this research, fruit losses will have the same meaning as food losses as per the FLI operational definitional framework as it includes the edible and inherent inedible parts of the fruit commodity group.

The term 'food waste' falls within the domain of the SDG Target 12.3 food waste indicator which is bound to the retail and consumption phases of the food supply chain. The term 'food waste' which is also directly linked to wasteful human behavior such as negligence or poor management (Beretta *et al.*, 2013), is seen to be synonymous with the term avoidable fruit losses within the processing stage of the food supply chain. However, from a fruit processing industry waste management perspective, 'fruit waste' refers to all the fruit parts (inedible or edible) that is either further repurposed or disposed of.

4.2 Sampling

This study targets the fruit loss flows of a selection of 18 types of fruit processed in South Africa. One of the well-known characteristics of processed fruit is that all inedible parts are removed. However, as the composition of inedible and edible portions of each fruit type differs, as well as their inherent losses associated with the processing method followed, the total fruit losses documented for each country will differ. Hence, the quantities as well as the configuration of fruit processed are unique to each country.

As discussed in Chapter 3, there are numerous methods to quantify food losses of a commodity group within the food value chain of a country. In order to gain comprehensive insights into the quantities of fruit losses generated, the sampling method used within this study involves a multi-method approach, combining direct and indirect quantification methods to calculate food loss quantities in weight, as set out in Figure 4.2. For reliable, representative and cost-effective data, a balance between indirect and direct quantification methods is encouraged (Corrado *et al*., 2019).

4.2.1 Indirect sampling method

The indirect sampling method used in this study is inferenced by calculation based on proxy data. Proxy data provides a quantitative estimate on the quantity of food losses or waste that occurs within a given commodity or stage within the food supply chain (CEC, 2019). It is used when it is not feasible (because of budget or time constraints) to access and measure all food loss data needed (FLW Protocol, 2016). However, when using proxy data to quantify fruit losses the limitation exist that adequate data may not exist, and available data may be unreliable as proxy data for estimating fruit losses (FLW Protocol, 2016). Also, because proxy data is gathered from external sources, the data cannot give insights into the root causes and hotspots of fruit losses within the South African fruit processing industry (CEC, 2019).

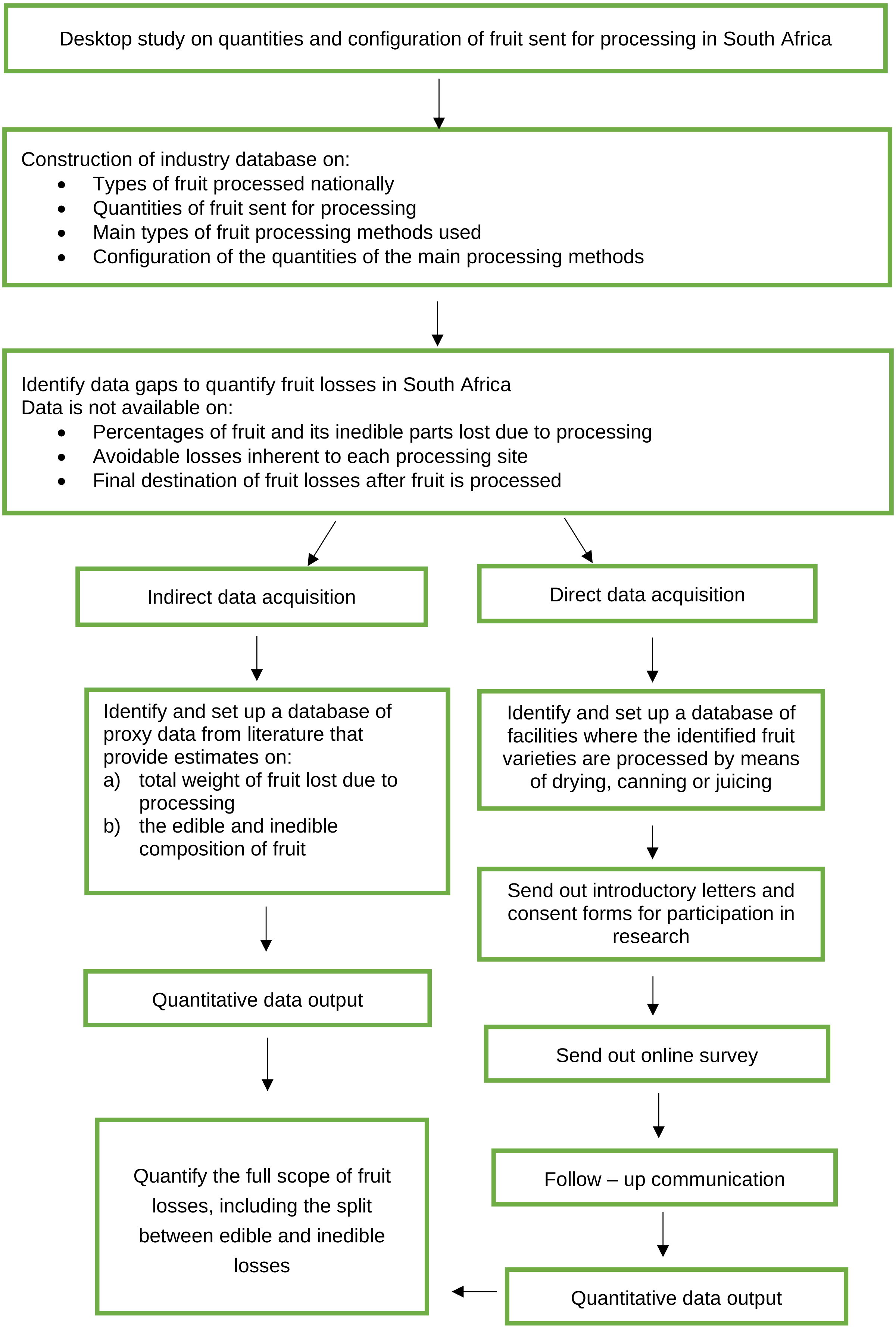

Figure 4.2 Overview of the data collection and quantification procedure followed

For this study, a literature search for existing fruit loss data (as a percentage of fruit input weight) was undertaken to serve as proxy data for inferring processing loss percentages for each of the selected 18 fruit types, within the configuration of the South African fruit processing framework to estimate the total fruit losses for the country. Secondly, following the approach Laurentiis *et al.,* (2018) used to calculate the inedible portions of fresh fruit by calculating the averages of inedible fruit portion data gathered from international nutritional databases, this study followed the same approach in order to establish inedible fruit portion conversion factors. The data on the inedible parts of the select 18 fruits processed in South Africa is important to effectively differentiate between the edible and inedible parts of fruit losses.

As argued by Champions 12.3, if government institutions or business establishments can measure and report food losses and its inherent inedible parts separately, then they should be able to apply the SDG Target 12.3 reduction targets only to the edible food portion (Champions 12.3, 2017). Subtracting the total inedible fruit losses of each of the selected 18 fruit types from the total fruit losses established represents the edible portions of fruit that is lost during processing as set out below:

Total fruit losses (TFL) = Total fruit processed x Calculated fruit loss percentage

Total inedible fruit losses (TIFL) =Total fruit processed x Inedible portion conversion factor

Total edible fruit losses = TFL – TIFL

One aspect of quantifying fruit losses according to the FLI definitional framework that is not addressed in this paper, as it is beyond the reach of the indirect quantification methods followed, is to obtain data on the final destinations of the losses of the selected 18 fruit types processed in South Africa. The end destination directly influences the quantification of food losses as the FLI operational definition clearly defines that only losses that do not re-enter the food supply chain in any other utilization can be classified as food losses (FAO, 2018). This information on the end destinations of food losses or on how food losses are utilized per fruit variety in South Africa is not readily available or documented in literature.

4.2.2 Direct sampling method

The direct sampling method used in this study involved a survey to quantify fruit losses in the fruit processing stage of the food supply chain in South Africa. Although the data collected through proxy data is extensive, data gaps are evident with regards to limited literature available on the processing losses of a few select fruit types, such as pear, apricot and pineapple which are included in this study. Additional data gaps include the lack of data on avoidable fruit losses, and the lack of information on the final destinations of fruit losses after processing and/or further utilization of fruit losses. These aspects of fruit loss generation are unique to each processing facility and can only be accessed through direct sampling methods.

Due to the limited time and finances available to gather primary data from all entities involved in fruit processing operations in South Africa, it was decided to conduct purposive sampling to acquire data from fruit processors that utilize one or more of the three main methods used for processing the selected 18 fruit types in South Africa, namely juicing, canning or drying, each contributing 84%, 11% and 3%, respectively (Table 4.1). Hence, the fruit processing entities that were targeted are all listed members of the South African Fruit and Vegetable Canners Association (SAFVCA), Canning Fruit Producers Association (CFPA), South African Fruit Juice Association and Dried Fruit SA. The information of the listed members of these associations can all be found on the respective association websites. A database of fruit processors was compiled that included 31 facilities in total. By means of an online survey, questions to collate existing data from the fruit processing facilities were circulated to the fruit processors. The topics for questions in the survey included:

i. Estimates of the quantities of each fruit type processed in weight
ii. Estimates of fruit losses inherent to the processing method used as a percentage of total fruit inputs – solid loss residues only (peels, pips, seeds, skins, pomace)
iii. Avoidable fruit losses (due to human behavior, mechanical failure, poor management)
iv. How fruit losses are utilized or disposed of (fruit loss final destinations)

Two limiting factors of using a survey to collect data in this study is that the data collected is dependent on a third-party reporting and that information can be limited by commercial sensitivities and confidentiality (CEC, 2019). Ethical clearance to conduct the current study was obtained from the Stellenbosch University research ethics committee (REC).

4.3 Data collection

Data sets with processing quantities and configurations of the predominant fruit types processed in South Africa are readily available from annual reports on the agriculture sector from the Department of Agriculture, Land Reform, and Rural Development (DALRRD), as well as reports from South African fruit growers [Deciduous fruit producers (HORTGRO), Citrus Growers Association (CGA), South African Subtropical Growers' Association (SUBTROP), Guava Producers Association)] and fruit processor associations [South African Fruit and Vegetable Canners Association (SAFVCA), Canning Fruit Producers Association (CFPA)].The combined dataset of fruit processing data consists of a 5-year average (2017-2021) of the quantities and configurations of fruit sent for processing in South Africa (Table 4.1).This data set of values (in weight) serves as baseline information to quantify fruit losses in the present study. However, not all the configuration data on the division of fruit processed by the three main fruit processing methods utilized in South Africa is available for all 18 fruit types covered in the study. The assumption is thus made that fruit with no configuration data available namely, cherry, banana, litchi, papaya, pineapple and granadilla are all sent for juicing.

Table 4.1 Fruit processing data (5-year average 2017-2021) of the quantities and configurations of 18 fruit types sent for processing in South Africa

Fruit	Processing method	2017 (Tonne)	2018 (Tonne)	2019 (Tonne)	2020 (Tonne)	2021 (Tonne)	Average Total (Tonne)	Average (%)	References
Apple	Dried	2 170	3 080	1 920	1 530	1 610	2 062	0.6	Hortgro (2021a); DALRRD (2017-2021)
	Canning	3 306	1 475	5 387	5 619	6 512	4 460	1.4	
	Juiced	297 254	244 433	278 132	345 574	400 471	313 173	98	
	Total	302 730	248 988	285 439	352 723	408 593	319 695	100	
Pear	Dried	15 204	9 088	6 888	6 573	6 888	8 928	5.5	Hortgro (2021a); DALRRD (2017-2021)
	Canning	36 534	27 774	40 489	58 301	60 242	44 668	27.8	
	Juiced	113 812	107 707	92 926	109 231	112 867	107 309	66.7	
	Total	165 550	144 569	140403	174 105	179 997	160 905	100	
Apricot	Dried	7 150	9 185	7 800	6 040	6 325	7 300	23	Hortgro (2021b); CFPA (2022)
	Canning	21 531	18 288	13 738	8 883	20 467	16 581	51	
	Juiced	13 177	8 601	8 824	3 859	8 339	8 560	26	
	Total	41 858	36 074	30 362	18 782	35 131	32 441	100	
Peach	Dried	13 200	12 353	12 078	12 018	12 590	12 448	10	Hortgro (2021b); CFPA (2022)
	Canning	96 003	80 545	74 636	80 896	81 400	82 696	68	
	Juiced	42 662	20 597	19 570	29 357	21 236	26 684	22	
	Total	151 865	113 495	106 284	122 271	115 226	121 828	100	
Plum	Dried	2 529	3 201	1 247	766	1 107	1 770	45	Hortgro (2021b)
	Juiced	2 822	1 539	2 179	3 320	858	2 144	55	
	Total	5 351	4 740	3 426	4 086	1965	3 914	100	
Cherry	Juiced	74	18	86	45	82	61	100	Hortgro (2021b)
Avocado	Pulped	5 220	9 000	8 060	7 437	8 683	7 680	60	SAAGA (2022)
	Oil Extraction	1 828	8 399	3 763	6 608	4 745	5 069	40	
	Total	7 048	17 399	11 823	14 045	13 428	12 749	100	
Pineapple	Juiced	64 115	71 436	87 181	91 062	90 754	80 910	100	DALRRD (2021)
Banana	Juiced	1 481	1 028	443	644	342	788	100	DALRRD (2021)
Litchi	Juiced	3 586	5 858	368	757	1 396	2 393	100	SALGA (2022)
Mango	Dried	15 526	12 695	9 906	17 218	14 692	14 007	26	SAMGA (2022)
	Atchar	30 000	30 000	25 000	30 000	25 000	28 000	52	
	Juiced	15 289	10 087	15 547	9 087	7 338	11 470	21	
	Total	60 815	52 782	50 453	56 305	47 030	53 477	100	
Guava	Dried	780	742	736	651	744	731	3	DALRRD (2021); GPO (2022)
	Canned	4 160	3 956	3 926	3 470	3 971	3 896	16	
	Juiced	21 058	20 026	19 875	17 565	20 101	19 725	81	
	Total	25 997	24 724	24 537	21 685	24 816	24 352	100	
Papaya	Juiced	1 762	1 157	1 236	2 881	1 309	1 669	100	DALRRD (2021)
Granadilla	Juiced	122	19	219	348	194	180	100	DALRRD (2021)
Orange	Juiced	190 354	317 164	477 514	217 777	243 220	289 206	100	CGA (2022)
Grapefruit	Juiced	80 543	128 210	131 173	100 471	92 440	106 567	100	CGA (2022)
Soft Citrus	Juiced	30 214	83 287	58 773	62 983	81 110	63 273	100	CGA (2022)
Lemon	Juiced	126 714	128 832	143 071	172 922	138 898	142 087	100	CGA (2022)

The literature search for proxy data on estimates of fruit processing losses of the selected 18 fruit types delivered estimations for 17 of the fruit types. Estimations on pear losses could not be sourced from literature and were gathered from survey data.

As the focus of the present study falls on the quantification of fruit losses in its solid form, it is assumed that the fruit losses from fruit canning and fruit drying are similar as the losses mainly include skins, peels, pips and trimmings (as discussed in Chapter 3). Representative proxy data on the inedible quantities of all the 18 selected fruit types could be collected from a combination of 6 international food composition databases as seen in Table 4.2.

Table 4.2 Inedible portions (%) of fruit based on international nutrition databases

Fruit	Inedible portion (%) (1)	Inedible portion (%) (2)	Inedible portion (%) (3)	Inedible portion (%) (4)	Inedible portion (%) (5)	Inedible portion (%) (6)	Average inedible portion (%)
Apple	13	15	10	8	8	13	11.2
Pear	15	16	10	12	8	12	12.2
Apricot	8	6	7		7	6	6.8
Peach	10	9	4	6		13	8.4
Plum	3	10	6	4	6	8	6.2
Cherry	8	14	14	15	10	9	11.7
Avocado	31	24	26			29	27.5
Pineapple	57	43	49	33	48	47	46.2
Banana	37	35	34	35	37	33	35.2
Litchi	38	28	40	28			33.5
Mango	37	29	29	32	31		31.2
Guava	10	2	12	2	20	0	7.7
Papaya	40	30	38	30	33		34.2
Granadilla	39	58	39	59	48		48.6
Orange	29	20	22	23	29	28	25.2
Grapefruit	29	30	50	31	51	35	37.7
Soft Citrus	22	17	23	25	25	20	22
Lemon	36	36	47	34	47	35	39.2

Data source:1) Public Health England, 2021, 2) Marletta et al. 2000, 3) Norwegian food composition tables, 2021, 4) Australian Food Composition Database, 2019 5) Swedish food composition tables, 2022, 6) Finnish Food Composition Database, 2021

The procedure followed to conduct the survey included an introductory letter sent to each of the facilities asking for assistance in providing contact information of senior managers within the organization who can assist in completing an online survey sent by email in order to gain insights into the fruit losses produced at the facility. The same introductory letter with an attached consent form and link to the online questionnaire was sent to the 15 sets of contact information received from the facilities. A period of two months was given to complete the online questionnaire. Data was collected during July and August 2022. After this timeframe, only two surveys were completed in full. Follow up correspondence asking for assistance in completing the questionnaire was sent, whereby a time extension was given of another month. No incentives were provided to respondents to complete the questionnaire.

From the database of 31 fruit processing facilities identified, the online questionnaire revealed a response rate of 13%, with a final sample size of four facilities. Only three of the four survey respondents supplied an answer to the question about estimates of fruit losses inherent to the processing method used. Unfortunately, with the low response rate from fruit processing facilities, the survey respondents do not provide a representative profile of all fruit processing facilities in South Africa. Fruit types processed by the survey respondents include apples, pears, peaches, apricots, plums, guavas and pineapples which together represent 23% of the 18 selected fruit types sent annually for processing in South Africa. The fruit processing methods covered by the survey respondents include juicing, in the form of fruit juice, fruit purees and concentrates, and canned fruit. The responses from the questionnaire are reflected in Table 4.3. Fruit loss ratios compiled from proxy data, in addition to the quantitative data from the survey responses on fruit losses generated from fruit processing facilities in South Africa are shown in Table 4.4.

Table 4.3 Overview of responses to questions from the online survey

Fruit processing facility	Fruit processed	Annual fruit processed (Tonne)	Final products	Quantity fruit losses during processing (% raw fruit input mass)	Quantity avoidable fruit losses during processing (% raw fruit input mass)	What parts of fruit losses are reutilised?	End destination of fruit losses not utilised
A	Pears	1 000	Canned pear	30	10	None	Land application
	Apricots	1	Canned apricot	20	10	Apricot pips are sold to pharmaceuticals where they use the kernel for medicinal purposes.	Land application
	Peaches	1 000	Canned peach	15	10	Peach the pips are sold for use in gardens.	Land application
B	Apples	36 000	Apple concentrate, puree and freshly pressed juice	50	5	Peels (5% of fruit losses) are treated with enzymes to extract sugars for clear juice production and to increase juice yields.	Animal feed
	Pears	12 000	Pear concentrate, puree and freshly pressed juice	50	5	Peels (5% of fruit losses) are treated with enzymes to extract sugars for clear juice production and to increase juice yields	Animal feed
	Apricots	3 000	Apricot concentrate and puree	58	5	Apricot pips are sold to pharmaceuticals where they use the kernel for medicinal purposes.	Animal feed
	Peaches	8 000	Peach concentrate and puree	43	5	Peach the pips are sold for use in gardens.	Animal feed
	Plums	2 500	Plum concentrate and puree	37	5	None	Animal feed
	Guavas	5 000	Guava puree	28	3	Pips (3% of fruit losses) are sold for use in guava flavoured yogurts.	Animal feed
C	Apples	150 000	Apple concentrate	Not disclosed	1.5-2.5	None	Animal feed
	Pears	23 000	Pear concentrate	Not disclosed	1.5-2.5	None	Animal feed
D	Pineapples	89 847	Pineapple concentrate	14-18	Not disclosed	None	Animal feed

Table 4.4 Fruit processing loss ratios compiled from proxy and survey data

Fruit type	Processing method	Processing losses (%)	Type of fruit losses	References	Estimated average loss value (%)
Apple	Juicing	25 - 50	Apple pomace (Skin and flesh: 95%, seeds: 2-4% and stems: 1% of total losses)	Bhushan et al.(2008); Grigoras et al.(2013); Perusello et al.(2017); Rabetafika et al. (2014); Facility B loss estimates (Table 4.3)	37.5
	Dried and canning	12.5 - 21	Peels: 7.5% - 13%, Seeds: 4-7%, Stems: 1%	Wolfe and Lui (2003); Rabetafika et al.(2014)	17
Pear	Juicing	50	Pear pomace	Facility B loss estimates (Table 4.3)	50
	Dried and canning	30	Skin, core and stem	Facility A loss estimates (Table 4.3)	30
Apricot	Juicing	58	Apricot pomace	Facility B loss estimates (Table 4.3)	58
	Dried and canning	19 - 38	Skin, seed and stem	Facility A loss estimates (Table 4.3); Natic et al. (2020)	28.5
Peach	Juicing	43	Peach pomace	Facility B loss estimates (Table 4.3)	43
	Dried and canning	10 - 15	Peel, kernel (10-15% of total losses) and stem	Natic et al. (2020); Facility A loss estimates (Table 4.3)	12.5
Plum	Juicing	25 - 37	Plum pomace	Sojka et al. (2015); Facility B loss estimates (Table 4.3)	31
	Dried	9	Seed: 9%	Natic et al., 2020	9
Cherry	Juicing	40 - 50	Cherry pomace (Seed: 15-27% of losses)	Yilmaz and Gokmen, (2013); Sezer et al.(2021)	45
Avocado	Pulping (Guacamole)	21 - 30	Skin: 6-14%, Seed: 15-16%	Barbosa-Martin et al. (2016); Mora-Sandi et al. (2021); Wong et al. (2014)	25.5
	Oil extraction	39 - 52	Skin: 6-14%, Seed: 15-16%, Flesh: 15- 20%	Woolf et al.(2009); Permal et al.(2020)	45.5
Pineapple	Juicing	14 - 18	Pomace	Facility D loss estimates (Table 4.3)	16
	Dried and canning	43 - 61	Skin: 30-42%, Core :9- 10%,Stem:2-5%, Crown:2-4%	Roda and Lambri, (2019); Bhat et al.(2022)	52
Banana	Juicing	30 - 40	Peels:30-40%	Oliveira et al. (2016); Gonzalez-Montelongo et al. (2010); Emaga et al. (2008)	35
Litchi	Juicing	30 - 40	Seed: 30%, Peel: 15%	Kaur et al. (2022); Punia et al. (2021)	35
Mango	Juicing, dried and preserved	35 - 60	Peel: 15-20%, Kernel: 7-24%	Yadav et al. (2021); Ajila and Rao (2013)	47.5
Guava	Juicing	25 - 30	Pomace (skin and seeds)	Kong and Ismail (2011); Kumar et al. (2022);Lima et al.(2019)	27.5
	Dried	15 - 32.5	Skin (15-20%) and seeds (15-50%)	Kong and Ismail,(2011);Kumar et al.(2022)	24
	Canning	15 - 20	Skin: (15-20%)	Kong and Ismail,(2011);Kumar et al.(2022)	17.5
Papaya	Juicing	35 - 45	Peel (20-25%), seeds (15-20%)	Chielle et al. (2016); Pavithra et al.(2017)	40
Granadilla	Juicing	60	Peel/rind:50%, Seeds:10%	Khuwijitjaru and Klinchongkon (2020)	60
Orange	Juicing	50 - 60	Peel: 30-36%, Juice sacs:18%, Seeds:1.2%	Bejar et al. (2011); Khule et al.(2019) ;Zema et al. (2018)	55
Grapefruit	Juicing	62	Peel: 40%, Juice sacs:21%, Seeds:1%	Zema et al. 2018	62
Soft citrus	Juicing	64	Peel: 37%, Juice sacs:21%, Seeds:6%	Zema et al. 2018	64
Lemon	Juicing	62	Peel: 43%, Juice sacs:16%, Seeds:3%	Zema et al. 2018	62

Chapter 5: RESULTS AND DISCUSSION

5.1 Summary of findings

This study investigated the potential quantities of fruit losses generated within the fruit processing stage of the food supply chain in South Africa. The annual estimated fruit losses were quantified into inedible and edible losses in order to report on food losses within a definitional framework that is aligned with SDG Target 12.3.

5.1.1 Total fruit losses (TFL)

The calculated quantities of TFL generated by the selected 18 fruit types processed in South Africa are presented in Table 5.1. These estimates are based on the averages or singular values, depending on the amount of data available, for fruit processing losses from literature data and from the survey responses in the present study (as seen in Table 4.4). Using the estimated average loss value for each fruit according to the processing methods applied, the fruit losses are quantified for each fruit type entering the processing stage of the food supply chain in South Africa. The calculated conversion factors for each of the selected 18 fruit types in Table 5.1, represents the percentage of total fruit losses per fruit type that is unique to the South African fruit processing configuration. The TFL for the country is estimated at 44% losses of the average quantity of fruit processed per year.

According to fruit processing loss estimates in a study by Oelofse and Muswema (2018b), fruit losses (or “fruit waste” as referred to in their study) amounts to 34% of fruit (by weight) that is processed in South Africa. This study based their fruit loss calculations on proxy data from a study by de Las Fuentes *et al.* (2014) that quoted the European Commission (2010) on fruit loss percentages. The percentages states that juice production from fruit generates between 30% and 50% losses (by weight), and that fruit canning and preservation generates between 5% and 30% losses (de Las Fuentes *et al.,* 2014). To calculate an estimate of the volume of losses from fruit processing, the afore mentioned study by Oelofse and Muswema (2018b) applied the average percentage losses during processing (40% for juice and 17.5% for canning and preservation) to the key fruits processed (deciduous fruit, sub-tropical fruit and citrus fruit) in South Africa during the 2012/2013 season.

Findings from the present study indicate that juice production from the selected 18 fruit types processed in South Africa, generates between 16% and 64% losses (by weight), and that fruit canning and drying generates between 9% and 38% losses. The average fruit loss percentage based on the fruit processing input quantities for juicing is 48% and canning and drying is 25% within the configuration of fruit processed in South Africa. Of the 44% total fruit losses, 40% is attributable to fruit juicing and 4% to fruit canning and drying.

Table 5.1 Estimated annual TFL generated during fruit processing in South Africa

Fruit	Processing method	Processing quantities (avg. 2017-2021) (Tonnes)	Estimated fruit losses (%)	Estimated total fruit losses (Tonnes)	Calculated conversion factor for fruit losses per fruit type (%)
Apple	Dried	2 062	17	351	37
	Canning	4 460	17	758	
	Juiced	313 173	37.5	117 440	
	Total	319 695		118 549	
Pear	Dried	8 928	30	2 678	43
	Canning	44 668	30	13 400	
	Juiced	107 309	50	53 655	
	Total	160 905		69 733	
Apricot	Dried	7 300	28.5	2 081	36
	Canning	16 581	28.5	4 726	
	Juiced	8 560	58	4 965	
	Total	32 441		11 771	
Peach	Dried	12 448	12.5	1 556	19
	Canning	82 696	12.5	10 337	
	Juiced	26 684	43	11 474	
	Total	121 828		23 367	
Plum	Dried	1 770	9	159	21
	Juiced	2 144	31	665	
	Total	3 914		824	
Cherry	Juiced	61	45	27	45
	Total	61		27	
Avocado	Pulped	7 680	25.5	1 958	33
	Oil	5 069	45.5	2 306	
	Total	12 749		4 265	
Pineapple	Juiced	80 910	16	12 946	16
	Total	80 910		12 946	
Banana	Juiced	788	35	276	35
	Total	788		276	
Litchi	Juiced	2 393	35	838	35
	Total	2 393		838	

Table 5.1 (continued)

Fruit	Processing method	Processing quantities (avg. 2017-2021) (Tonnes)	Estimated fruit losses (%)	Estimated total fruit losses (Tonnes)	Calculated conversion factor for fruit losses per fruit type (%)
Mango	Dried	14 007	47.5	6 653	48
	Atchar	28 000	47.5	13 300	
	Juiced	11 470	47.5	5 448	
	Total	53 477		25 402	
Guava	Dried	731	24	175	26
	Canning	3 896	17.5	682	
	Juiced	19 725	27.5	5 424	
	Total	24 352		6 282	
Papaya	Juiced	1 669	40	668	40
	Total	1 669		668	
Granadilla	Juiced	180	60	108	60
	Total	180		108	
Orange	Juiced	289 206	55	159 063	55
	Total	289 206		159 063	
Grapefruit	Juiced	106 567	62	66 072	62
	Total	106 567		66 072	
Soft citrus	Juiced	63 273	64	40 495	64
	Total	63 273		40 495	
Lemon	Juiced	142 087	62	88 094	62
	Total	142 087		88 094	
All 18 Fruit	**Total**	**1 416 495**		**628 777**	44

The CSIR's most recent report on national quantitative research on food (losses and) waste for South Africa, used the fruit loss estimates by Oelofse and Muswema (2018b) as proxy data for their study to estimate the total fruit loss quantities for South Africa (Oelofse *et al.* 2021). The study by Oelofse *et al*. (2021) calculated that 381 240 tonnes of fruit and vegetable losses occur annually in South Africa (based on the average annual fruit and vegetable FAOSTAT (2014-2018) input quantities). However, according to the findings of this study, the average amount of annual fruit processing losses amount to 628 777 tonnes (Table 5.1), which is almost 40% higher (based only on fruit loss values) than the estimated loss values of fruit and vegetables entering the processing stage in the study by Oelofse *et al.* (2021).

According to the quantities of the selected 18 fruit types sent for processing in 2021 (Table 4.1), a total of 641 905 tonnes of fruit losses was generated. As seen in figure 5.1 below, the losses from processing activities of apples (10%), oranges (9%), lemons (6%) and pears (5%) are responsible for the bulk of the 44% TFL generated from the fruit processing stage in South Africa in 2021.

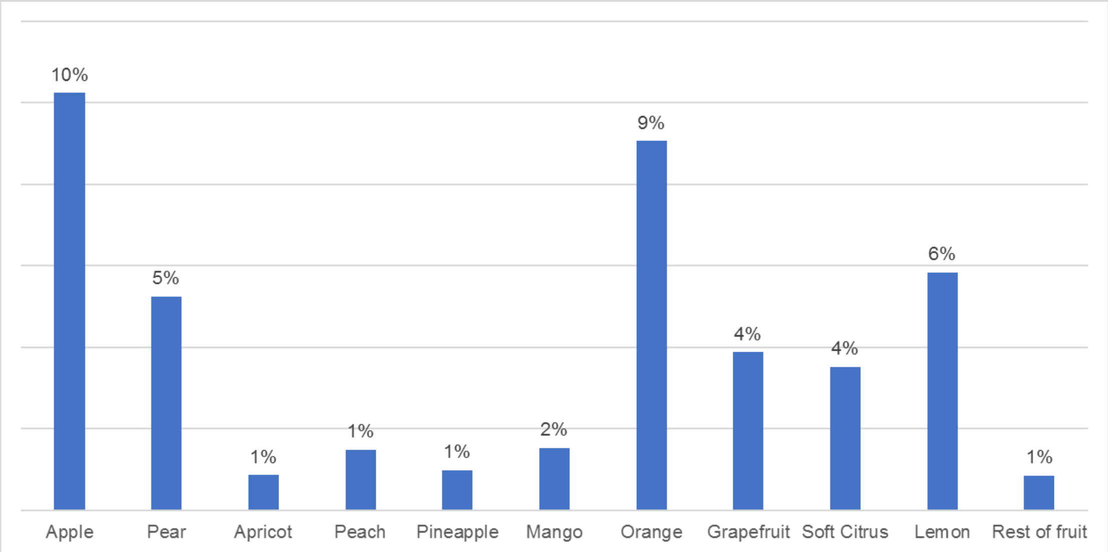

Figure 5.1 Configuration of the 44% TFL generated from the fruit processing stage in South Africa in 2021

5.1.2 Total inedible fruit losses (TIFL)

Fruit processing methods are known to produce large volumes of inedible losses in the form of peels, stems and seed fractions. These quantities of inedible fruit losses are ultimately inevitable losses (or 'waste' depending on the food supply stage) throughout the entire food supply chain. According to the unique configuration of fruit processed in South Africa, the calculated estimated quantity of TIFL amounts to 20% of losses of the approximately 1.4 million tonnes of the selected 18 fruit types sent for processing on average each year. The contribution of the TIFL for each of the selected 18 fruit types included in this study is depicted in Figure 5.2. The losses, apart from pineapple losses, are calculated by using the average inedible losses derived from Table 4.2 as a conversion factor, applied to the quantity of fruit sent for processing in 2021, as per the fruit quantities destined for processing in Table 4.1. The TIFL generated is estimated to be 284 282 tonnes in 2021.

Since the conversion factor of 46.2% in Table 4.2 for pineapple is much higher than the actual average losses of 16% reported from the survey data collected for the full quantity of pineapples processed by means of juicing in South Africa, the 1% of TFL originating from pineapple losses, as reflected in Figure 5.1 is considered to be inedible losses as seen in Figure 5.2. The total amount of pineapple quantities destined for fruit processing in 2021 is representative of the average pineapple quantities processed by Facility D on an annual basis, and as such the assumption is valid that the pineapples quantities processed in South Africa is predominantly juiced. The 20% TIFL generated from the selected 18 fruit types processed in South Africa consist mainly of citrus losses from processing oranges (4%), lemons (3.7%), grapefruits (2.4%) and soft citrus (1.2%), which together represent more than half of the TIFL generated in South Africa.

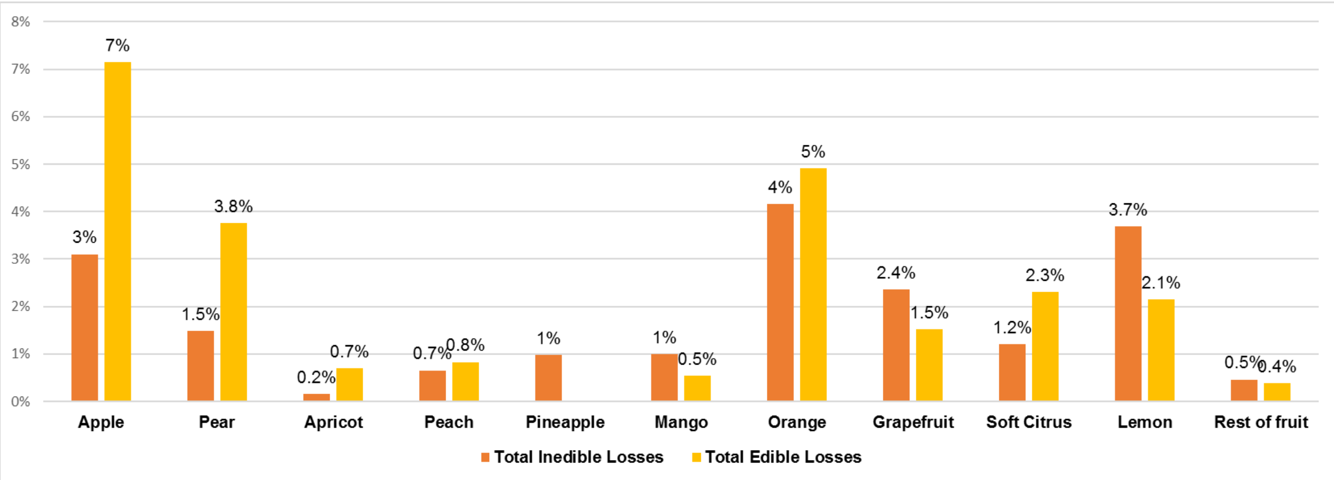

Figure 5.2 Configuration of the TIFL and TEFL generated from the fruit processing stage in South Africa in 2021

5.1.3 Total edible fruit losses (TEFL)

Not all fruit losses incurred during fruit processing are inedible losses. Large quantities of fruit losses consist of edible parts such as pulp and skins (as seen in Table 4.4) that is removed from the fruit during processing. Of the 1.4 million tonnes of fruit processed on average per annum in South Africa, just under a quarter (24%) are estimated to be edible losses. When establishing the quantity of fruit processing losses according to the FAO SDG Target 12.3.1 indicator, the TEFL of 24% represents the baseline for fruit losses in South Africa. TEFL estimates represented in Figure 5.2 is where the focus should fall when developing, deciding or implementing fruit loss reduction strategies within the fruit processing stage of the food supply chain in South Africa.
Most edible losses are from 5 fruit types, namely apples, oranges, pears, soft citrus and lemons representing 20% of the quantity (in weight) of the total input weight of the selected 18 fruit types sent for processing in 2021 (Figure 5.2).
Looking beyond South Africa's borders, Australia is a country that juices only 25% of the total quantities of apple that South Africa juice annually (Malhi et al., 2021). However, there is constant innovation within their food industry in developing apple products made from apple pomace which is available in the market as food ingredients such as apple – flour, seed oil, extract sweetener,

pectin, natural flavouring and fragrance oil (Malhi et al., 2021). All these products are reutilized within the food value chain, actively reducing the quantities of the edible losses of juiced apples.

5.2 Avoidable fruit processing losses in South Africa

The direct data on the estimates of avoidable losses in the present study was collected from four leading fruit processing companies, representing 22% of the fruit quantities processed within the fruit processing sector in 2021 in South Africa. The data obtained from the survey responses should be interpreted with caution due to the limited sample size. It provides only a limited glimpse into the fruit processing sector in South Africa and cannot be used to make statistically valid conclusions. According to the survey responses from fruit processing facilities (Table 4.3), 6 885 tonnes of additional fruit losses (from apple, pear, apricot, peach, plum and guava) can be attributed to avoidable losses that occur per annum. Avoidable losses within this study refer to losses (in weight) that is due to mechanical damage or human error which could have been prevented, and not due to the inherent losses from the selected fruit processing method applied. The data shows that even though the percentage losses differ significantly from 1.5% to 10%, fruit processing facilities do assess and document these losses. This is important because depending on when the avoidable fruit losses occur in the fruit processing operations, whether it is fresh fruit or fully processed (100% edible) fruit, these losses ultimately influence the food loss SDG Target 12.3 baseline estimates for each fruit processing facility.

5.3 Reutilization and final destination of fruit losses in South Africa

Only one of the fruit processing facilities that participated in the study indicated that they are actively improving the processing methods utilized at their processing facility to increase the final product outputs and to simultaneously reduce the quantities of fruit losses. Approximately 0.8% of the fruit sent for processing as reported by the survey responses, is reutilized within the food supply chain as edible food, as seen in Table 4.3. By far the majority (99.4%) of the total fruit losses available for each fruit processing facility, after any on-site reutilization, is removed from fruit processing facility to be further processed and reutilized as animal feed.

Fruit pomace, with its high carbohydrate levels and low protein and vitamin content, is not considered to be an optimal animal feed supplement (Malhi et al., 2021). However, fermenting pomace such as apple and pear pomace, reduce the inherent sugar content of the pomace and increase the protein content, making protein enriched pomace a productive ingredient to support the production of animal derived proteins (Malhi et al., 2021).

Prioritising “source reduction and reuse” of fruit losses to the top of the Food Recovery Hierarchy drives sustainability (Figure 5.3). “Source reduction and reuse” contributes both to the economic growth and job creation and to the reduction of environmental and social costs associated with waste management procedures (DST, 2014). Reutilizing fruit losses effectively into animal feed, can also be argued to be an effective source reduction and reutilization of fruit losses. However, as the fruit losses are not directly redirected back into the food value chain to be reutilized as food for humans, animal feed is not considered as a food loss prevention strategy to reduce food losses according to the FAO SDG 12.3.1 indicator (FAO, 2018)

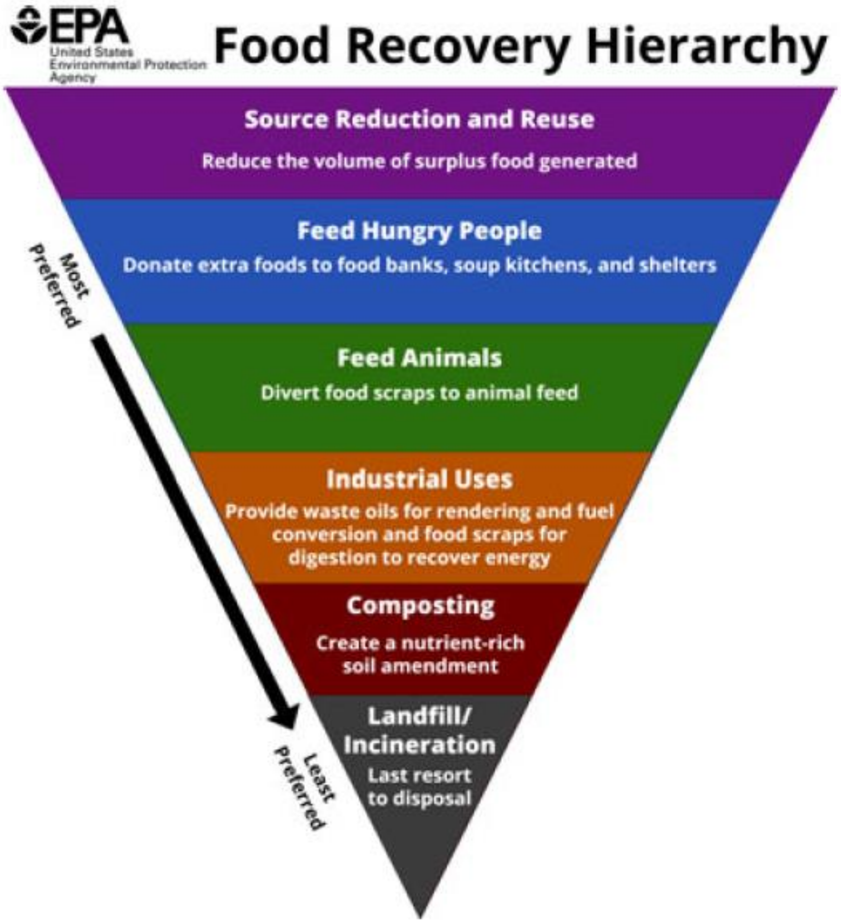

Figure 5.3 Food Recovery Hierarchy of the US Environmental Protection Agency

Chapter 6: CONCLUSIONS

Significant amounts of food losses occur in the fruit processing stage of the food supply chain in South Africa. The present study is the first food loss quantification study to follow a methodology to calculate the inedible and edible quantities of food losses that occur from fruit processing activities in South Africa. South African fruit processing data on the quantities (in weight) of fruit sent for processing, the types of fruit processed and the configuration of processing methods utilized is available and reported by the Department of Agriculture, Land Reform, and Rural Development (DALRRD), South African fruit grower associations and South African fruit processor associations. This study used both a direct data collection method with the use of survey questionnaires to generate new knowledge, along with indirect data collected from literature and statistical databases. The scope of the study was to estimate the quantity (in weight) of the total edible food losses in the fruit processing stage of the food supply chain in South Africa to ensure that the fruit processing stage in the food supply chain of South Africa is measured in accordance with the FAO SGD Target 12.3.1a indicator. As South Africa is committed to achieve SDG Target 12.3, the quantification of food loss data from all food commodities entering and exiting the upstream stages of the food supply chain is essential to formulate a food loss baseline for each of the 10 commodity groups (which fruit is one of) included in the FAO FLI.

The findings from the present study may be used by decision makers within government, business and the fruit processing industry to better understand the definitional framework of food losses that is aligned with SDG Target 12.3, and to determine where the food loss hotspots are for further research to design and implement targeted prevention or reutilization strategies for food loss reduction in the fruit processing stage of the South African food supply chain.

This study found that the total amount of fruit losses is estimated to be approximately 44% of the total input weight of the selected 18 fruit types sent for processing annually in South Africa. This 44% loss is further split into 24% edible fruit losses and 20% inedible fruit losses. Inedible fruit losses are an unavoidable aspect of the food supply chain, as it will ultimately be removed before reaching consumers, regardless of whether it is processed or not. Even though inedible losses are not quantified as food losses in the conceptual framework of the FOA Food Loss Index, it is still crucial from a waste management perspective to reutilize or valorize inedible fruit losses (Champions 12.3, 2017). A big limitation of the present study was that no information could be found on the reutilization and end destinations of fruit losses generated by the fruit processing stage. The limited information acquired from the fruit processing facilities that participated in the study is not statistically significant and could only provide partial insights.

It is recommended that research is undertaken on food losses in the fruit processing stage of the supply chain to improve the knowledge of current quantities of food losses and their final destinations. Any additional data and insights on utilizing edible food losses as a food ingredient in a safe and cost-effective manner can aid in accurately quantifying and reducing food loss in the fruit processing stage of the food supply chain.

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