Check weighing in table grape punnet packing: Opportunities in the development of operational effectiveness

by

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Abstract

South Africa is ranked as one of the largest table grape exporting countries in the world. The biggest markets for table grape exports have always been the EU and the UK, with emerging markets in Eastern Europe and Asia. The growing demand for pre-packaged fruit and vegetables in these markets are driven by factors like consumer comfort, hygiene and quality. These consumer needs have given rise to stringent quality control standards, putting more pressure on the producers to produce higher quality products.

This thesis investigates the use of check weighing as a tool to enhance the operational effectiveness of table grape punnet packing. It looks at the current state of table grape punnet packing in South Africa, then determines the operational effectiveness of current packing practices and finally evaluates the merits of using automated check weighing as an operational management tool to improve current systems.

Producers primarily make use of unskilled labour for the pre-packaging of table grapes, making it difficult to consistently produce good quality products. Some packing systems guide the operators towards filling punnets to the specified mass; some packing systems also feature internal check weighing in some form. Although these features improve mass accuracy and hence product quality, the packing processes are still prone to human and machine errors. Producers employ internal quality controllers who try to identify and rectify any human or machine errors as soon as possible.

The PPECB, a local statutory body, enforces the minimum quality standards for South African exports by means of inspectors checking random product samples during production. If products of sub-standard quality are found (including under mass), the whole batch needs to be checked and repackaged where necessary, at great cost to the producer.

Pre-packaged products may be produced according to the minimum mass system or the average mass system. The average mass system reduces the amount of raw product giveaway and increases revenue, but it requires that all products are check weighed and the masses recorded with a specified level of accuracy.

The addition of automated final product check weighing saw a significant reduction in the occurrence of under as well as over mass punnets. It also managed to improve the productivity of some packing systems. Subsequent experiments with the check weigher using different setup parameters yielded much better measurement accuracy and would reduce under and over mass punnets even more.

Considering the potential costs of having to repack batches due to the discovery of under mass products, it would be viable to implement automated final product check weighing even for small producers, with a payback period of less than 5 packing seasons depending on the producer’s specific pack house layout.

The implementation of check weighing could not only reduce the risk of sub-quality products being produced, but also open up entirely new market opportunities in a very competitive market for products produced to the average mass system.

Opsomming

Suid-Afrika is een van die grootste tafeldruiwe-uitvoerders ter wêreld. Die hoofmarkte vir tafeldruiwe-uitvoere was nog altyd die Europese Unie en Verenigde Koninkryk, met opkomende markte in Oos-Europa en Asië. Die groeiende behoefte vir voorafverpakte vrugte en groente in hierdie markte word gedryf deur verbruikersfaktore soos gemaksugtigheid, higiëne en kwaliteit. Hierdie behoeftes het tot gevolg gehad dat strenger reëls en regulasies vir kwaliteitsbeheer ontstaan het. Dit plaas ekstra druk op produsente om hoër gehalte produkte te produseer.

Hierdie tesis ondersoek die gebruik van weging van die finale produk as ŉ hulpmiddel om die operasionele effektiwiteit van die verpakking van tafeldruiwe te verbeter. Daar word gekyk na die huidige toestand van die verpakking van tafeldruiwe in Suid-Afrika. Die operasionele effektiwiteit van bestaande verpakkingstelsels word bepaal. Die meriete van ŉ "weging van die finale produk stelsel" as bestuurshulpmiddel is nagevors. Daar word ook bespreek of die stelsel as bestuurshulpmiddel aangewend kan word om die effektiwiteit van huidige verpakkingstelsels te verbeter.

Produsente maak primêr gebruik van ongeskoolde arbeid om tafeldruiwe te verpak. Dit maak dit moeilik om konstante goeie kwaliteit te lewer. Sommige verpakkingstelsels begelei die operateur om bakkies van ŉ spesifieke massa te produseer. Sommige verpakkingstelsels bevat ŉ interne toetsweeg funksie van een of ander aard. Alhoewel die funksies die akkuraatheid, produkmassa en dus produkkwaliteit verbeter, kan menslike- en masjienfoute steeds ŉ impak hê op die verpakkingsprosesse. Produsente maak gebruik van interne kwaliteitsbeheerstelsels wat poog om menslike- en masjienfoute so gou moontlik op te spoor en te herstel.

Die PPECB, 'n staatsliggaam, dwing die minimum Suid-Afrikaanse uitvoerstandaarde af deur middel van inspekteurs wat lukraak produkte tydens produksie ondersoek. Indien die produkte nie aan die kwaliteitstandaarde (insluitend massa) voldoen nie, moet die hele pallet nagegaan word en die bakkies moet reggemaak word waar nodig, teen 'n groot onkoste vir die produsent.

Voorafverpakte produkte kan volgens die minimum- of gemiddelde-massa sisteme geproduseer word. Die gemiddelde-massa sisteem verminder die hoeveelheid druiwe wat weggegee word en verhoog dus inkomste, maar dit vereis dat elke bakkie met 'n bepaalde akkuraatheid geweeg moet word. Daar moet ook rekord gehou word van die massas.

Die byvoeging van geoutomatiseerde finale produk toetsweging het 'n aansienlike verbetering in die hoeveelheid oor- en ondermassa bakkies tot gevolg gehad. Dit het ook die produktiwiteit van party verpakkingsstelsels verbeter. Daaropvolgende weër eksperimente met ander opstellingsparameters het baie beter akkuraatheid getoon en dus kon die hoeveelheid oor- en ondermassa bakkies selfs verder beperk word.

Met inagneming van die kostes daaraan verbonde om 'n pallet oor te pak as gevolg van ondergewig bakkies, sou dit selfs vir klein produsente die moeite werd wees om finale produk toetsweging te implementeer. Dit het 'n terugbetalingsperiode van minder as vyf pakseisoene, afhangend van die produsent se spesifieke pakstooruitleg.

Nie alleen kan die implementering van finale produk toetsweging die risiko van ondergewig produkte verlaag nie, maar dit kan ook nuwe markgeleenthede oopmaak vir gemiddelde-massa produkte in 'n baie kompeterende mark.

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Table of contents

List of figures

List of tables

Glossary

BRC	British Retail Consortium
Conventional packaging	The packaging of table grapes into plastic bags typically making up a 4,5kg carton
EU	European Union
GMO	Genetically Modified Organism
HACCP	Hazard Analysis and Critical Control Point
ISO	International Standards Organisation
NPV	Net Present Value
OE	Operational Effectiveness
Poka-yoke	A Japanese term that means "mistake-proofing"
PPECB	Perishable Products Export Control Board
Punnet packaging	The packaging of table grapes into small polymer containers, typically 500g
QC	Quality controller
SA	South Africa
TDCA	Trade, Development and Cooperation Agreement
TNE	Tolerable Negative Error
TQM	Total Quality Management
UK	United Kingdom

1. Introduction

The South African table grape export industry is ranked among the largest in the world, exporting most of its total produce to the European Union and the United Kingdom. South Africa is well known for its high quality grapes and is regarded as the preferred country of origin for quality and tasty grapes (Ntombela, S., 2010). With the emergence of new markets for pre-packed table grapes, this reputation of quality may be at stake. Pre-packaged table grapes are subject to strict quality specifications including product mass. The packing process is very labour intensive and seasonal workers with a limited formal education may be prone to error. Micro-managing the packing process is an option, but does not suit the industry due to its labour intensiveness (Smit, R. *et al*., 2011). Another option may be 100% final product check weighing to ensure mass conformity.

In this thesis the focus will be on the use of check weighing as an option to improve operational effectiveness. Section 1.1 provides a background of the industry to be studied. Section 1.2 proposes automated check weighing as a solution to the identified problem. The specific research goal to be studied in this thesis is given in Section 1.3, the research design and methodology in given in Section 1.4 and the chapter is concluded with a layout of the rest of the thesis in Section 1.5.

1.1 Background

Since the first few crates of table grapes were exported to the United Kingdom in 1886, the South African table grape industry has seen significant growth both in terms of market expansion and production capacity (Ntombela, S., 2010). In 2011 South Africa exported over 56 million 4,5kg cartons of grapes, ranking it as the third largest table grape exporting country in the world (Barrientos, M. and Soria, C., 2012).

Just over 80% of the exported grapes were sent to markets in the European Union (EU) and United Kingdom (UK), with the majority of the rest destined for the Middle East, Far East and Asian markets (PPECB, 2012).

As with diversifying away from traditional European and UK markets towards emerging markets in the East, there is also a movement towards pre-packaging table grapes into containers (punnets) for export as a more convenient alternative to the conventional way of packing grapes into plastic bags. In recent years there has been an increase in the proportion of table grapes exported as punnets, feeding a growing demand for pre-packaged fruit in the EU and the UK.

Despite the increased marketability and higher price associated with pre-packaged fruit, it is considerably more labour intensive than conventional packing and requires more packaging material. It is also subject to more stringent quality regulations. One key issue with punnets is ensuring the minimum net mass without giving away too much grapes. Mass errors detected during an inspection may lead to significant financial penalties to the producer. Many producers are not prepared to take the risk of producing punnets and then lose out on entering an expanding market.

Table grape producers make use of many seasonal workers during the packing season to harvest and pack the grapes. Unfortunately these people often have a low level of education and literacy (Greeff, P. and Kotzé, M., 2007) and may find it difficult to master the packing practices, resulting in quality problems (especially mass related ones for the scope of this study). Micro-managing the packing process is an option, but does not suit the industry due to its labour intensiveness (Smit, R. *et al*., 2011).

In an economy constantly under pressure from the rising cost of labour, electricity, fuel, fertiliser, water, packaging material, transport, etc., producers simply cannot afford to produce products of sub-standard quality.

1.2 Proposed solution

From Section 1.1 there is clearly a need for an innovative and cost effective solution of mass quality control that requires very little labour. Such a proposed solution exists in the form of an automated check weigher. As an operational management tool, a check weigher could be added to the output end of any production line to automate the process. Products passing over the check weigher would be checked for both a lower and an upper mass limit and separated from the production line if not within these allowable limits.

From an operational management point of view there would be much to gain from the addition of such a system. Firstly all products would be checked to comply with the minimum mass requirements. Secondly the allowable mass bandwidth could be decreased without the risk of products being under mass (packing system may have mass tolerances), this could decrease giveaway and improve on operational effectiveness of the packing system. Thirdly, with a check weigher handling the mass quality control aspect of all products, the Quality Controllers may focus their attention on other quality factors such as berry size and colour.

Although, theoretically, this seems to be a good solution, the use of check weighing in table grape punnet packing first needs to be thoroughly evaluated.

1.3 Research goal

The goal of this thesis is to evaluate the use of check weighing as a tool to enhance the operational effectiveness of table grape punnet packing and can be accomplished through completing the following sections and the subsequent steps.

1.3.1 Determine the state of table grape punnet packing in South Africa

1.3.1.1 Determine the market prospects for table grape punnet packing

1.3.1.2 Determine South Africa’s competitiveness in the global table grape market

1.3.1.3 Identify quality aspects applicable to the process

1.3.1.4 Determine the influence of labour on table grape punnet packing

1.3.2 Determine the operational effectiveness of current packing practices

1.3.2.1 Find the packing technologies and practices used in the table grape punnet packing industry

1.3.2.2 Determine the productivity of current packing practices

1.3.2.3 Determine the accuracy of current packing practices

1.3.2.4 Determine the statistical parameters of under mass punnet occurrence and the financial implications thereof

1.3.2.5 Determine if conventional quality control methods are effective

1.3.3 Evaluate automated check weighing as an operational management tool

1.3.3.1 Find the definition of an operational management tool

1.3.3.2 Determine the requirements for automated check weighing

1.3.3.3 Determine if the check weigher satisfies the requirements

1.3.3.4 Determine if under mass punnets can be eliminated effectively using automated check weighing

1.3.3.5 Perform a costing analysis for implementing check weighing

Once all fourteen steps have been completed, the use of check weighing as an operational management tool to improve operational effectiveness can be evaluated. The reader will be informed throughout the rest of the thesis whenever a step has been completed.

The use of automated check weighing is expected to have a positive effect on the operational effectiveness of a punnet producing pack house through ensuring better mass conformity.

1.4 Research design and methodology

The thesis is structured around the research goal and the steps to achieve it. Four main studies will form part of the thesis in order to complete the fourteen steps. First is a literature review, to get as much information as possible from past studies; the second study comprises a need assessment survey conducted among table grape producers via structured interviews; the third study is a productivity study conducted at a few large table grape pack houses in the Northern Cape province of South Africa during the 2011/2012 packing season; and the fourth study consists of check weigher experiments to determine the ideal parameter setup for accuracy and to determine if the check weigher used during the productivity study met the user requirements. Figure 1.1 shows an overview of the research design.

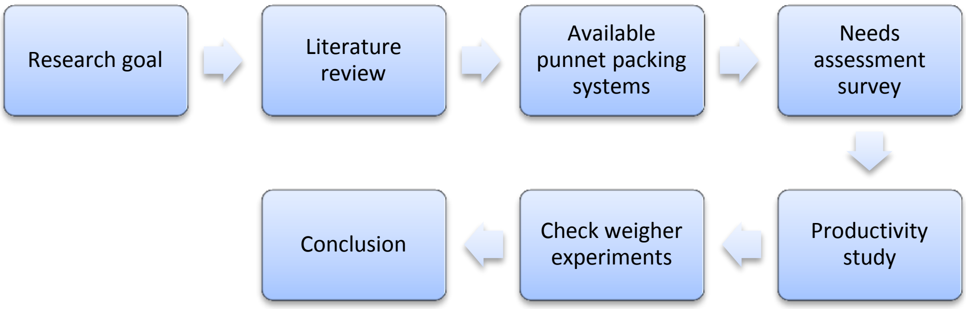


Figure 1.1: Overview of research design

1.4.1 Literature review

The literature review will be conducted to provide a background of the research field and to complete steps 1.3.1.1, 1.3.1.2, 1.3.1.3, 1.3.1.4, 1.3.3.1 and 1.3.3.2 of the research goal.

It will be conducted by reviewing all available literature on the research field to create the background needed to complete the steps of the research goal.

1.4.2 Available punnet packing systems

This study will be done to complete step 1.3.2.1 of the research goal.

Available punnet packing systems and their functioning will be found in literature and through conducting interviews with the users of the systems as well as the manufacturers.

1.4.3 Needs assessment survey

The needs assessment survey will be conducted as a first step towards determining if the implementation of check weighing is a necessary field of study. It will aim to complete steps 1.3.2.4, 1.3.2.5 and 1.3.3.5 of the research goal.

It will be conducted via structured telephonic interviews upon completion of the 2010/2011 packing season with the information still fresh in the heads of the interviewees. The method of structured telephonic interviews is chosen because it allows the interviewer to be in charge of the interview and to elaborate if anything is unclear. The questionnaire is shown in 0.

The interviews will be conducted among a randomly chosen group of twenty punnet producers and three export companies representing all table grape producing regions in South Africa. The data from the completed surveys will be added into a database and processed.

1.4.4 Productivity study

The productivity study will be conducted as an empirical study to get raw data for calculating the productivity and accuracy of packing systems. This study will complete steps 1.3.2.2, 1.3.2.3 and 1.3.3.4 of the research goal.

The study will be conducted at Karsten Farms in the Northern Cape of South Africa. The study will be conducted by author and three undergraduate students covering seven different pack houses and five different punnet packing systems over six weeks.

During the study the data will be captured onto a generic template designed to fit all the packing systems. Data from all the students will be consolidated once per week and some preliminary processing done to uncover any irregularities of missing data. The captured data will also be verified against Karsten Farms' internal information systems' records.

Upon completion the data will be analysed and processed to calculate the necessary parameters.

1.4.5 Check weigher experiments

The check weigher experiments will be conducted to determine the accuracy, sensitivity to disturbances and maximum speed of the unit used during the productivity study and will complete step 1.3.3.3 of the research goal.

Experiments will be conducted both in a factory setup to simulate the pack house environment and in a controlled laboratory setup. Experiments are to be repeated in both environments to determine the check weigher's sensitivity to external sources of disturbance.

For the experiments, a punnet with a specific mass would be weighed successively to determine the accuracy of the check weigher. The experiment will aim to determine the optimal parameter setup for accuracy. For the maximum speed test, three different punnets will be weighed successively with different following distances to determine the minimum allowable following distance.

1.5 Thesis layout

The second chapter in this thesis is the literature review. The literature review starts by discussing previous studies on table grape packing, followed by sections on market research, the supply chain, human resources, quality aspects and factors influencing it, check weighing systems as operational management tools, table grape packing productivity and is concluded with a summary of the most important findings.

Chapter 3 introduces all the different punnet packing systems mentioned and evaluated in the thesis.

Chapter 4 gives the results from the needs assessment survey. It starts with a profile of the table grape producers interviewed, followed by a summary of the different strategies used for training, managing the packing processes and performing quality control. The next section focuses on quality control as well as the reported under mass punnet detection frequencies. The fourth section states the penalties incurred for rejected pallets and ends with a calculation of the expected payback period for implementing check weighing for different sized producers. The demand for check weighing as reported by the survey is discussed in the next section and the chapter is concluded with a summary of the main findings.

In Chapter 5 the results from the productivity study is discussed. It starts by discussing the punnet packing systems used in this study and how they were implemented, followed by the throughput for each system in terms of capacity and productivity. The next section is on packing system accuracy and looks at the achieved punnet mass distributions and giveaway for each system, followed by a validation of the effect of check weighing. The effect of management and training is discussed in the next section and the chapter is concluded with a summary.

The sixth chapter shows the check weigher experiments' results. It starts with an introduction to the check weigher and its functioning followed by a description of the experimental and check weigher setups. The next sections give the results from the factory and laboratory experiments and the chapter is concluded with a summary.

The thesis is concluded in Chapter 7.

2. Literature review

In this chapter relevant literature is discussed to provide a background to the research field and to expose a void which it is expected could be filled by this specific research. The literature review also aims to complete as many of the steps towards achieving the research goal set in Section 1.3 as possible, through the following: discussing previous studies in the relevant field; providing market research and future prospects; exploring the table grape supply chain; discussing human resource management; exploring the changing nature of quality demands from the consumer and the resulting quality standards, as well as the factors influencing product quality; operational management is discussed, with the emphasis on operational effectiveness development, as well as the use of automated check weighing as an operational management tool; and, lastly, a measure for productivity is defined.

2.1 Introduction

Many articles have been written on the table grape packing process; however the majority are focused on pre- and post-packing practices and merely mention the action of packing portions of grapes into bags or containers. Pre- and post-packing practices include the preparation of grapes for packing while still on the vine; the pre-cooling of cut bunches before packing; the packaging material used for packing the grapes; the cooling process of packed grapes and the transport of packed grapes from the producer to the client abroad as discussed in Section 2.3.1. This section will discuss articles focused specifically on systems used for pre-packing table grapes into punnets.

Productivity of punnet versus carton packing in the table grape industry (Koegelenberg, M., 2010):

In this final year BEng dissertation two alternative systems for improving punnet packing were compared to traditional punnet and carton packing in order to determine whether it would be financially feasible for producers to invest in new punnet packing technology.

The two alternatives were the conveyor combination system (Section 3.2.2) and the local storage combination system (Section 3.2.1). A simulation model was created to perform a Net Present Value (NPV) analysis for each of the alternatives based on specific production data, labour constraints and increases in the cost of labour and packaging material over a fifteen year period.

This dissertation had two definitions for productivity: the daily capacity of a system; and the total yield production to be processed in a specific pack house. These were used to calculate the number of operational days required for each system in the NPV analysis.

The results of the simulation showed that the conveyor combination system had the highest net present value, followed by the local storage combination system, traditional carton packaging and, lastly, traditional punnet packaging.

New developments in grape punnet packaging (Verwey, N. *et al*., 2012):

The aim of this article was to compare the conventional way of packing punnets (Generic scale system, Section 3.1.1) with a newly developed system (Microcontroller-assisted scale system, Section 3.2.3) and a combination system (Local storage combination system, Section 3.2.1) in terms of productivity and effectiveness. The conventional and combination systems are based on the philosophy of division of work to achieve economy of scale benefits, while the new system integrates the process steps at a single workstation.

This article is based on part of the productivity study used in Chapter 5 of this thesis, which was conducted at one of the largest table grape pack houses in the southern hemisphere.

The first comparison was of productivity, measured in punnets per person per minute. The microcontroller-assisted scale system was found to have a productivity 4,9 times higher than the other systems. The comparison of giveaway indicated that the integrated packing system had the least giveaway and the combination system the most.

A comparison of quality control compared the number of loose berries per punnet, the number of bunches per punnet and the number of defective berries per punnet. The combination and microcontroller-assisted scale systems had the least number of loose berries per punnet, indicative of their small amount of handling of the grapes. Due to the method it uses, the combination system had the least number of bunches per punnet, followed by the microcontroller-assisted scale system. The microcontroller-assisted system had the greatest number of defective berries per punnet, exceeding the allowable amount according to quality standards. This was because one worker had to cut, trim and pack the grapes to mass in as little time as possible.

The article concluded by stating that integrated packing was the better option for productivity and had the least amount of grape handling, but that more stringent management would be needed in order to reduce the defective berries per punnet to an acceptable number.

In the first article it was shown that the use of a technological solution for packing punnets would increase income over conventional punnet and carton packing. The second article shows how much more productive the new integrated work station method of packing is than the conventional production line method of packing. Although these articles focus on packing system productivity, there clearly is a research void with regard to packing system accuracy and error occurrence.

The following two articles were written as part of this research study to be incorporated in the thesis:

Economic requirements analyses for table grape check weighing (Smit, R. *et al*., 2011):

This conference article was based on part of the needs assessment survey to be discussed in Chapter 4 and was written leading up to this thesis (see Addendum B). It investigated the frequency of occurrence of under mass punnets by means of structured interviews conducted among table grape producers. The probable financial cost resulting from pallet rejections due to under mass punnets was also determined from the survey, and the article concluded with a presentation of the capital amount producers could profitably spend to eliminate under mass punnets.

Table grape punnet packaging: The influence of check weighing (Smit, R. *et al*., 2012):

Based on part of the productivity study discussed in Chapter 5, this Journal article was also written leading up to this thesis (see Addendum A). The article focused on human and machine errors as reasons for the deviations in punnet mass. Check weighing was introduced as an option for effectively reducing out-of-specification punnets.

Results showed that the goal of 100% mass quality could not be met using a generic check weigher, although a significant decrease in the number of under mass punnets was observed. Human and machine errors were once again to blame for not reaching the goal, and the article concludes with recommendations for improving the check weighing process by reducing the chances of human and machine error.

The first article discussed the frequency of occurrence of punnets with mass defects and argued that producers could profitably eliminate these punnets by implementing check weighing. The second article discusses the results of implementing check weighing and the effect of human and machine errors on the effectiveness thereof.

Although some of the literature has already been demarcated in the last two articles, the literature review for the thesis aims to thoroughly discuss available writings.

2.2 Market research

The market research section will look at the current market situation and prospects for the table grape industry as a whole, then at the more specialised market for pre-packaged table grapes and lastly it will look at the implementation and requirements of packing to the average mass system, as opposed to the conventional way of packing to the minimum mass system. By determining the market prospects for table grape punnet packing, this section will complete step 1.3.1.1 of the research goal.

2.2.1 Market for table grapes

Agriculture in South Africa is rather a small part of the national economy and accounts for about 3% of the gross domestic product (Republic of South Africa, 2012). Deciduous fruit production contributes about 32% to the agricultural sector (Greeff, P. and Kotzé, M., 2007) and fresh table grapes account for about 32% of the total deciduous fruit production (Siphugu, L., 2012).

The table grape export industry showed only limited growth during the 1980s and early 1990s. This was a result of export sanctions during the apartheid era (Levy, I., 1999) and also due to the regulation of the industry. Export sanctions were lifted 1987 and a slow, but steady, growth in table grape exports was observed, see Figure 2.1 (Barrientos, M. and Soria, C., 2012). Following deregulation of the industry in 1996, table grape exports saw a significant growth rate for a few years (Ortmann, F.G., 2005). With the newly deregulated market open for trade and the South African rand declining compared to the UK Pound and the Euro, there was a significant increase in private export enterprises. This quickly resulted in foreign markets being flooded with class 2 fruit (see Section 2.5.1) and a subsequent dramatic lowering of fruit prices in 1998. Many smaller farmers and exporters suffered great losses and were either liquidated or closed down with the effect visible in Figure 2.1, with the sudden drop in export growth that took from 1998 to 2001 to partly recover. The country's reputation as producer of quality fruit also suffered due to the flooding of the market by class 2 products. To ensure that the situation does not arise again, the export of class 2 fruit has now been banned and fruit exports are subject to strict guidelines (Ortmann, F.G., 2005).

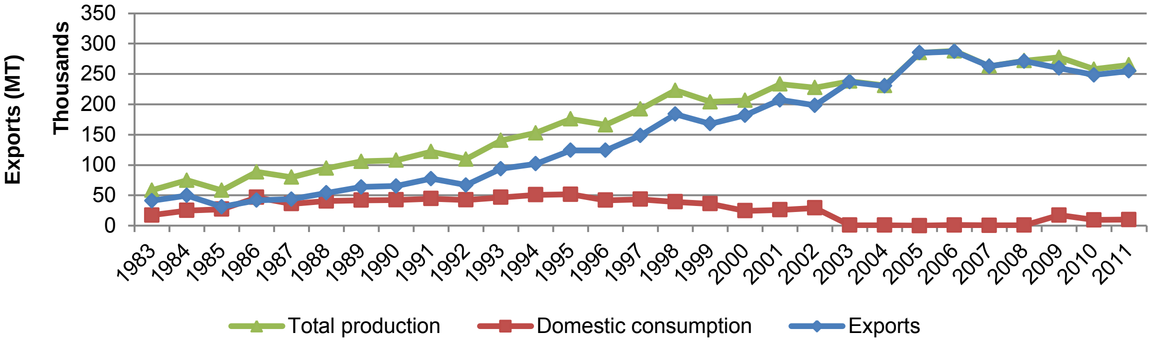


Figure 2.1: South African table grape production

Source: Own graph created with data from Barrientos, M. and Soria, C., 2012

As a result of South Africa's strong European roots, it has always had easy access to the traditional UK and EU markets, governed by the Trade, Development and Co-operation Agreement (TDCA) (Ntombela, S., 2010). The aim of the TDCA is to create an area of free trade between South Africa and the EU member states, with great successes to date (Republic of South Africa Department of Foreign Affairs, 2009). During the 2011/2012 season more than 80% of the total table grape production was exported to the EU and UK markets with only 19% exported to the Middle East, Far East and Asia, see Figure 2.2 (PPECB, 2012).

Besides being the traditional markets and having the TDCA agreement, this bias towards markets in Europe and the UK could also be attributed to the high exchange rate of the Rand against the Euro and UK Pound; the well-developed internal infrastructure to allow rapid mobility within the EU markets; the geographic location of the UK and EU markets, which are closer to South Africa and allow for shorter shipping times than is the case for the major southern hemisphere rivals.

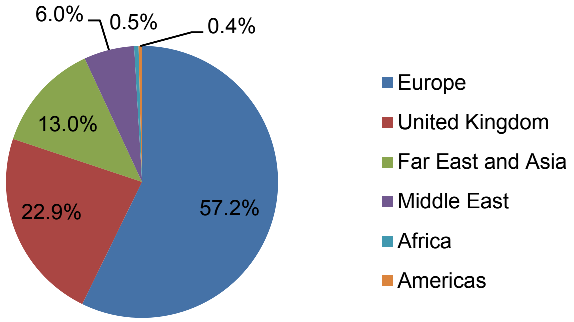


Figure 2.2: South African 2011/2012 season table grape export destinations

Source: Own graph created with data from PPECB, 2012

During the last few years the UK and EU markets have been under constant pressure from the economic downturn (Siphugu, L., 2011), the strengthening Rand against the Euro and UK Pound and the growing supply from other Southern Hemisphere countries. The effect can be seen in Figure 2.1, with a definite stagnation and eventual decline of exports since 2006.

Further downward pressure is caused by the EU Customs Advanced Manifest Rule, effective since January 2011 (Siphugu, L., 2012; Maersk Line, 2012). The rule aims to ensure the performing of risk assessment before any goods enter the European Union, and applies to all 27 EU member states. It requires an Entry Summary Declaration (ENS) to be submitted 24 hours prior to the cargo being laden on board a vessel that will enter the EU, regardless of the final destination. Appropriate risk-based controls are performed according to the ENS, primarily for safety and security purposes. This will result in even more stringent quality standards and will undoubtedly increase the costs of packing table grapes.

Hence there has been a visible shift away from the traditional markets towards new emerging markets in Far East and Asia as well as the Middle East with 5% and 1% growth in exports from 2007/2008 to 2011/2012 respectively, see Figure 2.3 (Siphugu, L., 2012; PPECB, 2012). These are the most populated regions of the world and penetration into these markets could be invaluable to the growing South African table grape industry. With an increasing supply of goods and foodstuffs from these countries to South Africa, the key to successful market penetration may prove to be mutual trade (Greeff, P. and Kotzé, M., 2007).

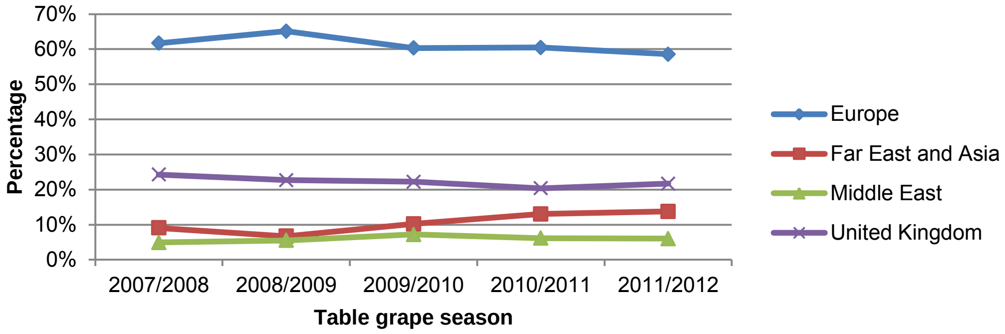


Figure 2.3: South African table grape export destination history

Source: Own graph created with data from PPECB, 2012

Despite the pressure on traditional markets and the shift towards emerging markets, South Africa is still actively marketing in the UK (Siphugu, L., 2011) and supporting campaigns like 5 A-Day to supply nutrition criteria and assist in the promotion of fruit and vegetables in a healthy diet (Pollard, C.M. and Rowly, C., 2009).

2.2.2 Market for pre-packaged table grapes

In Section 2.2.1 the focus was on the market for table grapes and the direction it's moving towards. This section will focus on the market for pre-packaged food and specifically for table grapes packed into punnets.

Pre-packaging of table grapes into punnets is used to present the grapes more attractively, make them easier to handle, improve hygiene, ensure better quality and keep the grapes fresh for longer (Koegelenberg, M., 2010). According to the German Insurance Association, one risk factor associated with the export of table grapes is mass loss during shipping, due to a reduction in moisture content (German Insurance Association (GDV), 2012). To compensate for the 2% to 3% mass loss producers need to add more grapes, thus increasing giveaway. By using punnets as packaging, the moisture loss can be reduced, and hence also the amount of giveaway.

In an interview with the CEO of the Karsten Group, Piet Karsten (Snr.), he stated that the group was putting a lot of effort into promoting table grape punnets as a quality product. This was proving to be a difficult task, because punnets had previously been used as a way of adding value to class 2 fruit that was typically of low quality (Karsten, P. (Snr.), 2012).

An increasing trend among Western European consumers is to choose their foods according to convenience (Codron, J.M. *et al*., 2005) and to change their diets to include more higher value products than in the past (Gehlhar, M. and Regmi, A., 2005). The consumer food choice is still influenced by price and quality; however, the consumer definition of quality has changed in recent years and is today more closely associated with sensory attributes, health attributes, process attributes and convenience attributes. Convenience attributes refer to the time or energy saving nature of the food and its packaging.

Despite concerns that packaging materials are wasted (Hellström, D. and Saghir, M., 2007; Codron, J.M. *et al*., 2005; Shewfelt, R.L. and Henderson, J.D., 2003), a market study revealed that display space devoted to pre-packaged fruit and vegetables in United Kingdom and European supermarkets has increased to 71% and 70% respectively during the past decade (Vernin, X., 2005). Other sources also indicate a consumer shift towards pre-packaged foods in the United States, Canada and Australia as a result of campaigns to promote fruit and vegetable intake (Shewfelt, R.L. and Henderson, J.D., 2003; French, S.A. and Stables, G., 2003; Vinning, G. and Tshering, C., 2005; Maneepun, S., 2005).

According to a study based on retail sales data, Eastern European consumers are growing more sophisticated, with a greater demand for healthy and convenient products, especially among the wealthier consumers (Gehlhar, M. and Regmi, A., 2005). Consumers in Latin America and in developing Asian countries are showing similar changes in demand to those in Eastern Europe, while Western European markets are fast approaching maturity for pre-packaged food, with market growth generally associated with the growth in population (Codron, J.M. *et al*., 2005).

2.2.3 Market for average mass pre-packaged products

The average system was first introduced in the UK in 1980; before that, all pre-packaged products had to comply with the minimum system (that is, the quantity had to be at least that indicated). However it was difficult and required a lot of effort to comply with this original average system and table grape exporters elected to remain with the minimum system.

In 2006 the regulation was revised as part of a programme to simplify UK weights and measures law (United Kingdom Department for Innovation, Universities and Skills, 2007).

Most pre-packaged products with predetermined mass or volume are subject to the average system. Filling processes have an inherent degree of variation and the aim of the average system is to regulate acceptable tolerances for variation. This will protect the purchaser against buying under mass products and will protect businesses against unfair competition (United Kingdom Department for Innovation, Universities and Skills, 2007). Under the average system a proportion of products is allowed to fall below their stated mass within a predetermined tolerance. Any product to which the average system applies, must bear the E-mark shown in Figure 2.4. The mark must be clearly visible and in close proximity to the nominal quantity.

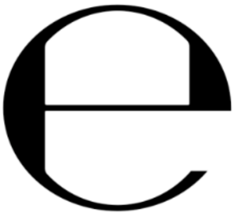


Figure 2.4: The E-mark for the average system of weights and measures

Source: European Communities, Secretary of State, 2006

The regulation sets out three rules with which producers must comply for the average system (United Kingdom Department for Innovation, Universities and Skills, 2007; European Communities, Secretary of State, 2006):

1. The average actual contents of the packages should not be less than the nominal quantity;
2. The proportion of packages that are short of the nominal quantity within the tolerable negative error (TNE) may not be more than a specified level; and
3. No packages may be short by more than twice the TNE.

For products between 300 g and 500 g the TNE is 3% of the nominal mass and for products between 500 g and 1000 g the TNE is fixed at 15 g (European Communities, Secretary of State, 2006). Any product with contents of less than the nominal quantity minus the TNE is considered defective.

The regulations lay down procedures of a reference test for statistically checking the compliance of batches with the three rules given above. The reference test comprises two parts: the measuring of the actual contents of each package; and the measuring of the average contents of each batch (European Communities, Secretary of State, 2006). A batch is equal to the maximum hourly output of the packing line. The sampling plan applicable to punnets is set out in Table 2.1. Depending on the batch size, the number of packages to be checked should be equal to or greater than the number in the sample. If the number of defective packages (tolerance greater than TNE) is less than or equal to the acceptance criterion, the batch is acceptable.

Table 2.1: Requirements for checking batches of packages

Number in batch	**Number in sample**	**Number of defective packages**	
		Acceptance criterion	**Rejection criterion**
100 to 500	50	3	4
501 to 3200	80	5	6
3201 and above	125	7	8

Source: European Communities, Secretary of State, 2006

Under the new regulations it is the duty of the producer to ensure that all products comply with the three rules, this may be accomplished by either total final product check weighing or through checking the contents by sampling, as set out in Table 2.1 (United Kingdom Department for Innovation, Universities and Skills, 2007).

If compliance with the average system is to be ensured, it must be supported by mass records. If no records are available, it may only be used for compliance with the minimum system. Records must be kept for at least one year. These requirements for check weighing to be used for the average mass system partly completes step 1.3.3.2 of the research goal.

The law on weights and measures is enforced by inspectors (United Kingdom Department for Innovation, Universities and Skills, 2007). In South Africa these inspectors are employed by the PPECB (PPECB, 2011). These inspectors may enter pack houses, conduct reference tests and inspect and test any packing equipment and records for compliance. Should an inspector have reasonable grounds for doubt, he has the power to instruct a producer to hold certain packages until the question is resolved. An inspector may also instruct a producer to review the method of checking packages for mass conformance, should he believe that it is not appropriate, with the intention of preventing future failures.

Under the regulation, it is considered an offence to knowingly sell any package with a negative mass tolerance of more than twice the TNE or to knowingly sell a package that comes from a batch that has failed the reference test, unless evidence of corrective action can be supplied or it can be proven that the package has the correct mass.

The average mass system is designed to protect both the consumer and the producer. It allows for a proportion of the punnets to be below the nominal mass within specified limits. By implementing the average mass system a producer can save on give-away, and therefore be more productive.

2.3 Table grape supply chain

The table grape supply chain is a complex linkage of various role players, from the table grape producers through organised labour, NGOs, financial institutions, government, exporters, transporters, importers and other traders. This section will focus on the main aspects of the supply chain, as well as South Africa’s competitive position in the global table grape market, in order to complete step 1.3.1.2 of the research goal.

2.3.1 The export process

The focus of this thesis is only on a very small, but key, step in the table grape export process. In order to provide the reader with an understanding of the processes involved in the table grape industry, the supply chain processes for the growing, picking, packing, cooling, transportation to the port, handling at the port and shipping of exported table grapes will be broadly discussed as described by Ortman (Ortmann, F.G., 2005).

During the year the vines need to be prepared for the coming season by trimming and training the shoots to maximise fruit bearing. After budding the number of bunches per vine is limited to ensure appropriate nutrient supply to the fruit. Bunches are trimmed by workers to be of a certain size and shape. Visually unfavourable berries are removed as well. Meanwhile the harvest needs to be protected against pests and weeds without jeopardising the quality and health safety of the fruit.

Once the grapes are ripe, they are ready to be harvested within a small time window. Bunches must be picked before 09:00 in the morning to prevent damage from the heat. They are then transported to the pack house and put in a pre-cooler room to be cooled down to 18°C. Both the pack house and pre-cooler room are kept at high humidity. The lower temperature and high humidity reduces transpiration and helps prevent loose berries.

In the pack house, bunches are checked for quality and berry size and pruned into the desired bunch size and shape according to the client’s preference. Bunches are then packed to the preferred mass, 500 g punnets in this case. At this point an internal quality controller normally conducts quality checks on random chosen samples. Filled punnets are packed into cartons and packaging material is added to help preserve the grapes; cartons contain between 9 and 11 punnets, depending on the client. Cartons are then packed onto pallets and labels with the relevant information are added. A pallet may contain 115 to 120 cartons of punnets. The pallets are then subject to quality inspection by an official inspector of the PPECB and either cleared for export or rejected until the fault has been corrected (Republic of South Africa Department of Agriculture, Forestry and Fisheries, 2012; PPECB, 2011).

The cleared pallets are transported to regional cold stores and force cooled to -0,5°C (berries will not freeze at this temperature because of the high sugar content, which lowers the freezing point of water) (Jie, W. *et al*., 2003). Care must be taken to maintain this temperature throughout the rest of the journey to ensure quality. At the pack house a thermocouple is fitted to the centre of each pallet and used to log the core temperature throughout the journey (Morokolo, B., 2011).

From the cold stores, pallets are transported in refrigerated containers to the Fresh Produce Terminal or Container Terminal at any of the ports. The containers are loaded onto freight ships and transported to their destinations. The shipping takes 12 to 14 days from Cape Town to Europe. Early in the season some producers also send pallets by air freight to get their grapes first onto the market, at very high prices. However, this is a very expensive option.

2.3.2 South African supply chain competitiveness

In 2011 South Africa was ranked as the third largest table grape exporter in the world, after the USA and Chile, see Figure 2.5 (Barrientos, M. and Soria, C., 2012). Both South Africa and Chile have the physical advantage of counter-seasonal production to the large Northern Hemisphere markets. South Africa also has the advantage of shorter shipping times to the EU and UK.

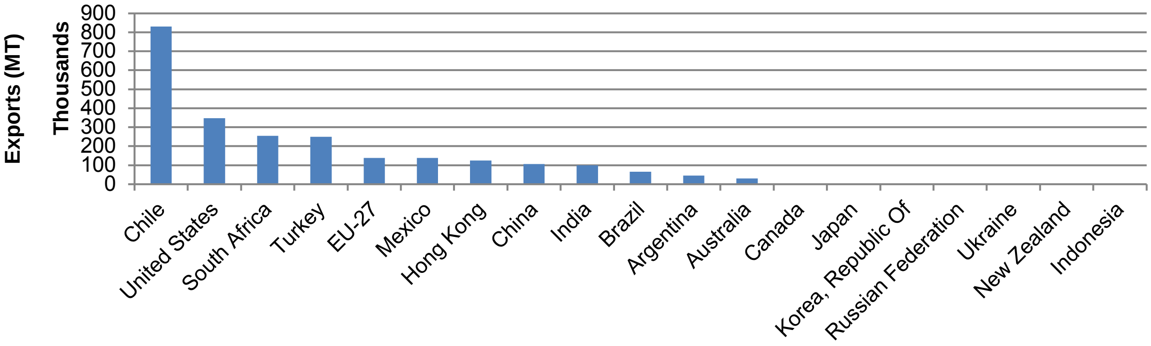


Figure 2.5: Table grape exports per country 2011

Source: Own graph created with data from Barrientos, M. and Soria, C., 2012

A 2007 study that compared the relative competitiveness of the South African and Chilean deciduous fruit supply chains found the South African deciduous fruit industry to be less competitive than its rival, Chile (Mashabela, T.E., 2007). However, the study also indicated that the competitive trend for most of Chile's deciduous fruit products was negative, while South Africa, on the other hand, showed positive trends.

The study proceeded to identify factors which exerted a negative influence on South Africa's competitiveness in the deciduous fruit industry. Among the factors identified were the scarcity of skilled labour; the cost and quality of unskilled labour; the cost of technology and the lack of timely and accurate feedback information (Mashabela, T.E., 2007).

In this section labour and technology were shown to be important factors in the success and competitiveness of the deciduous fruit supply chain. Both were identified as problem factors which need to be addressed.

2.4 Human resources

According to the South African Government, about 8,5 million people are directly or indirectly dependant on agriculture for their employment and income (Republic of South Africa, 2012).This is more than 16% of the total population recorded during the 2011 census (Republic of South Africa Statistics, 2012). Table grape production is more labour intensive than that of other deciduous fruit, requiring labour for six to seven months, from the commencement of vine growth in spring to the picking and packing of the grapes in summer (Greeff, P. and Kotzé, M., 2007; Morokolo, B., 2011). This section provides a background on human resources and their influence on the table grape industry and will partly complete step 1.3.1.4 of the research goal.

The following case study was compiled, by the author, on Karsten Farms (one of the biggest table grape producers in the Southern Hemisphere) regarding their human resource development strategy (Karsten Group Holdings, 2009):

> At Karsten they believe that their strength lies in their people and their strategy is to bring out the best in their staff through social development.
>
> The company employs over 600 permanent staff and up to 5000 migrant labourers during the harvesting season. Housing is provided for all the staff, permanent and migrant, together with their families (International Finance Corporation, 2005). On the farms they are provided with meals and have access to crèches, on site clinics and sports facilities. Sports teams are sponsored by the group.
>
> The group also provides transport to the nearest school, if one isn't located on the farm. Retired permanent staff members may keep their houses and still have access to the clinic.
>
> The group provides many life-skills training programmes in conjunction with the government, such as the teaching of reading and writing skills. There is a resident minister on each farm to carry out social programmes aimed at developing leadership skills and building up self-confidence. These programmes are carried out through discussions and counselling and subjects covered include marriage, drug abuse,

> HIV/Aids, youth, leadership and child care. On the job training is provided for the seasonal workers in order to equip them for the production of world class fruit. Seasonal workers who show potential are identified and offered the opportunity of becoming permanent employees. Permanent employees are assisted with career planning and should each have a training plan for improving themselves in such a way that they are ensured promotion when a vacancy arises.
>
> Karsten has developed HIV/Aids programmes on the farms to create awareness and to support affected workers, estimated at 20% of the workforce. An awareness manual has been created and is distributed, together with training, by peer group leaders and the minister. Affected workers are helped to enrol in the Government's programme of free therapy and anti-retroviral medication. They have also launched "Get to Know Your Status" programmes to create more awareness and improve the health of workers on the farm.
>
> These social development programmes have made Karsten a well-respected business throughout the entire country and overseas. About 70 to 80% of the seasonal workers employed by the company return again the following year.

Limited formal education and low levels of numeracy are often associated with seasonal labourers (Greeff, P. and Kotzé, M., 2007; Dolan, C.S., 2004; Treurnicht, N. F. *et al*., 2005). Many social problems like absenteeism, alcohol abuse and family strife, as well as poor health, are also associated with seasonal labourers. These prove to be challenges in the quality assurance of products (Smit, R. *et al*., 2012). The case study was compiled to show the efforts being made by producers to reduce the effects of these challenges. Although Karsten Farms is a very big entity, smaller farms have similar human resource development programmes under the Social Accountability standards required by EU and UK customers.

2.5 Quality

In a consumer-driven world, product quality is of utmost importance. The Oxford Dictionary defines quality as the standard of something as measured against other things of a similar kind (Oxford Dictionaries, 2010), with the standard of a product determined by a bundle of certain attributes (Sterns, P.A. *et al*., 2001). Quality attributes for consumer goods are divided into two groups, namely physical and perceived quality attributes. This section will focus on the influence the consumer has on product quality, the resulting quality standards and factors influencing product quality and, therefore, complete step 1.3.1.3 of the research goal.

2.5.1 Consumer influence

The focus of approaches to quality management such as Six Sigma and TQM increasingly shift towards customer satisfaction, with the voice of the customer defining what quality is (Breyfogle, F.W. III, 2003; Fliess, A., 2007).

Quality, as perceived by the customer, can be divided into four types of attribute; sensory attributes, health attributes, process attributes and convenience attributes (Grunert, K.G., 2003; Finch, Byron J., 2008; Hanf, J.H. and Kühl, R., 2005). The different attributes are described in Table 2.2.

Table 2.2: Quality attributes for consumers

Quality attribute	Description
Sensory attributes (Physical)	Taste, appearance, smell, mass
Health attributes (Perceived)	Communicated through labels, marketing and education.
Process attributes (Perceived)	Naturalness/organic, traceability, chain transparency, environmental considerations, products produced with due concern for equitable income distribution, GMO-free
Convenience attributes (Perceived)	Aspects of product which save time or energy

Source: Summarised from Grunert, K.G., 2003; Finch, Byron J., 2008 and Hanf, J.H. and Kühl, R., 2005

Grunert refers to surveys carried out in several European countries at two points in time to determine the importance of various attributes of food quality (Grunert, K.G., 2003). The surveys showed that consumers in France, Germany and the UK regard taste and health attributes as the most important and also showed a rise in the importance of the convenience attribute. Breyfogle considers the conformance of product mass to specification to be an important attribute as well (Breyfogle, F.W. III, 2003).

In order to standardise some of the quality attributes, table grapes are classified in three classes by the World Health Organisation (World Health Organisation, Food and Agriculture Organisation of the United Nations, 2012).

Table grapes in the ‘Extra’ Class must be of superior quality. The shape and colouring of bunches must be characteristic of the variety, with the berries firm and firmly attached to the stalk with even spacing. Bunches must be free of defects, with the exception of slight superficial defects, so long as these do not affect the general appearance or quality of the package.

Class 1 table grapes must be of good quality with the shape and colouring allowed to be slightly defective. The berries must be firm and firmly attached to the stalk with the spacing allowed to be less even than for the ‘Extra’ Class. Slight sun scorching, affecting the skin only, may also be allowed.

Class 2 table grapes may be defective in shape and colouring, with slight sun scorching, bruising and skin defects, provided these do not impair the quality, keeping quality and presentation of the packages. The berries must be sufficiently firm and sufficiently attached to the stalk, with less even spacing than in Class 1.

These classifications, as well as other quality attributes, are enforced through numerous quality standards. The most common of these standards are discussed in the next section.

2.5.2 Quality standards

Quality standards are laid out as a result of consumers, retailers, importers and other distributors’ preferences. Some standards are legally required in order to govern the quality of imported produce, while others are not legally required, but market-specific requirements and demands. Some of the mandatory legal requirements differ between importing regions. A discussion of the most common standards and requirements follows:

BRC - Global Standards for Food Safety: The standard has been developed to assist manufacturing organisations in complying with their legal obligations towards food safety in order to produce food products of consistent quality and safety. It protects the consumer by providing a basis by which a competent third party is able to audit and certify the supplier. Furthermore it may assist both retailers and producers in their defence, should they be prosecuted under the EU food law (BRC, 2005; HACCPEUROPA, 2012).

EU Marketing Standards: These govern the quality and labelling of fruit and include regulations for diameter, mass and class specifications. Any produce that does not comply with these standards may not be sold on the EU markets (Morokolo, B., 2011).

Eco-Labels: European consumers are becoming increasingly aware of environmental issues and are lobbying against purchasing non-environmentally friendly or non-sustainable produce. Eco-labels such as the EU Eco-Label, the Netherlands Milieukeur, the German Blue Angel and the Scandinavian White Swan are designed to make environmentally friendly produce more easily recognisable. Although they are voluntary, they can afford an exporter a marketing edge (Morokolo, B., 2011).

Fairtrade: Fairtrade is a group of organisations working together to secure better prices for producers by setting international standards. These standards are designed to support the sustainable development of small producer organisations and agricultural workers in the poorest countries in the world. The standards include common principles on social development; economic development; environmental development and forced and child labour (Fairtrade International, 2011).

General Food Law: This is EU legislation and covers procedures of food safety and hygiene, including the traceability of food (Morokolo, B., 2011).

GlobalG.A.P.: This is a voluntary set of worldwide standards for the certification of agricultural products around the globe. Initially named EurepGAP, the organisation aimed to harmonise standards and procedures for Good Agricultural Practice (G.A.P.) in the European continent and has since grown global as the new name suggests. It serves as technical communication platform for continuous improvement and transparency across the entire food chain. The certification covers food safety and traceability; the environment; the health, safety and welfare of workers; integrated crop management; integrated pest control; quality management system and HACCP (GLOBALG.A.P., 2012).

Hazard Analysis and Critical Control Point (HACCP): HACCP is a systematic preventative approach to food safety management. It addresses physical, biological and chemical hazards during all stages of food production and preparation as a means of prevention, rather than final product inspection. HACCP is relevant to all sectors of the food industry in order to demonstrate compliance with national and international food legislation requirements (HACCPEUROPA, 2012; South African Bureau of Standards, 2011).

ISO 9001: This standard specifies the requirements for a quality management system to enhance customer satisfaction by assuring continuous product improvement. Under this standard an organisation is required to present proof of process improvement should there be customer complaints regarding quality (International Standards Organisation, 2012; South African Bureau of Standards, 2011; HACCPEUROPA, 2012).

ISO 14001: The ISO 14001 standard specifies the requirement for an environmental management system. It is applicable to any organisation wishing to establish, implement, maintain or improve an internationally recognised environmental management system. This includes environmentally friendly packaging and waste reduction (International Standards Organisation, 2012; South African Bureau of Standards, 2011).

ISO 22000: This standard specifies the requirements for a food safety management system. It integrates the HACCP principles with the proper steps developed by the Codex Alimentarius Commission (a commission concerned with developing the necessary steps to implement international food standards, guidelines and codes of practice). It requires all possible hazards that may occur in the food chain to be identified and assessed beforehand in order to establish an effective combination of control measures (International Standards Organisation, 2012; South African Bureau of Standards, 2011; HACCPEUROPA, 2012).

PPECB: PPECB is an independent organisation that controls all perishable exports from South Africa. The organisation has ISO 9001:2000 certification as well as GlobalG.A.P. accreditation and acts as an independent service provider of quality certification and cold chain management services. It also delivers statutory inspection and food safety services through pack house and cold chain inspections during the packing season (PPECB, 2011).

Social Accountability: The Social Accountability 8000 (SA 8000) certification deals with issues such as child labour, health and safety, discrimination, disciplinary practices, working hours and remuneration. It requires an annual on-site audit and is seen as a necessary tool for successfully accessing any European market (Morokolo, B., 2011; Euro Cert Asia, 2012).

Tesco Nature's choice (TNC): TNC is a standard required by all fresh produce growers supplying to Tesco. The standard encompasses GlobalG.A.P. and continuous improvement practices, but with specific application to the Tesco group. Additionally, the standard also acts as an open communication channel between the producer and the customer (Euro Cert Asia, 2012; Cox, S., 2007).

There are numerous sets of standards, most of which require producers to continuously improve their production processes as effectively as possible and with the smallest environmental and social impact. Another common denominator is traceability throughout the production and supply chain processes, facilitated by open communication channels between the producer and consumer.

The next section will focus on common issues affecting the quality of products, which provide opportunities for process improvement.

2.5.3 Human and machine error

Kolarik identifies two types of manufacturing error; namely machine errors and human errors (Kolarik, W.J., 1995). This section discusses the various causes of error applicable to table grape packing operations and completes step 1.3.1.4 (the influence of labour on punnet packing) of the research goal.

All packing systems require an initial setup at the beginning of each day or after being restarted during the day. Some require the scales to be tared individually with an empty punnet (subtracting the mass of an empty punnet from the measured mass) to ensure correct net mass (Smit, R. *et al*., 2012). Others require setup via a central computer. Most machine errors occur during the initial setup as a result of human error. An operator may not notice that anything is wrong and could unknowingly be delivering defective punnets, putting the company at risk (Liu, H. *et al*., 2009).

The human performance curve, produced by Yerkes-Dodson, is shown in Figure 2.6. It relates human performance to the levels of arousal, stress and anxiety experienced. Humans differ and it is difficult to predict what level of stress or arousal will result in acceptable performance (Kolarik, W.J., 1995).

During the day levels of stress and arousal fluctuate, which result in peaks just before lunch and again later in the afternoon when packers become exhausted with impaired performance and cognitive ability due to the monotony of the process and long hours (Eichele, T. *et al*., 2008; Dahlgren, A., 2006; Bourne, L.E. and Yaroush, R.A., 2003).

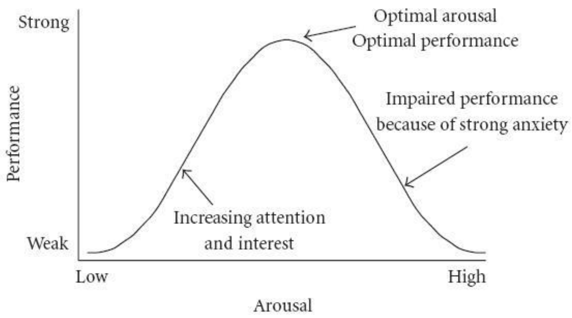


Figure 2.6: Yerkes-Dodson Human Performance Curve

Source: Diamond, D.M. *et al*., 2007

A human error is an action occurring beyond the limits defined by the system (Kolarik, W.J., 1995). Many types of human error are defined, but two of these are most applicable to the table grape industry; namely errors of omission, where part of a task is omitted and errors of commission, where a task is performed incorrectly. Due to the monotony of the packing process, packers tend to develop shortcuts for some actions and may even omit non-mandatory steps such as internal check weighing (refer to Section 3), if they judge it to be unnecessary (Smit, R. *et al*., 2012). During times of high levels of stress and arousal, with performance below acceptable limits, the probability of human error increases (Zeo, E. *et al*., 2009) and packers may often perform simple actions incorrectly.

The most common machine error in table grape packing systems is load cell drift. A load cell is a transducer that converts force into an electrical signal. A strain gauge measures deformation as an electrical signal, because the effective electrical resistance is changed by strain in the load cell. Load cell counts may drift during operation, due to the effect of temperature on electrical resistance (Houston, W.V., 1952). Another reason for load cell drift could be static build up on the load cell. Static builds up because of changes in humidity. The strain gauge measures very small changes in voltage and a static discharge may cause the mass reading to drift (Hardy Process Solutions, 2012).

It has been shown that the occurrence of both human and machine errors is inevitable during the packing process, and may result in defective packages being produced, putting the producer at risk of penalty. The risk of occurrence of these errors may be reduced by improving the processes or by implementing final inspection of products.

2.6 Operational management

Finch defines operational management as the management of the resources a business uses to create value (Finch, Byron J., 2008). He further argues that without resource management, a business will not be able to operate effectively and will ultimately fail. Operational management therefore involves the continuous improvement of processes that utilise resources (Porter, M.E., 2001).

This section will focus on the development of operational effectiveness and discuss the suitability of automated check weighing as a possible operational management tool in the development of operational effectiveness.

2.6.1 Operational effectiveness development

Porter argues that management is a two-sided coin, with strategy on the one side and operational effectiveness (OE) on the other and that a company cannot achieve success by having one without the other (Porter, M.E., 2001). The development of operational effectiveness is grouped into four activities that form a supporting cycle as shown below in Figure 2.7.

In order to continuously improve the performance of a functional unit, managers lead and control the activities of the company, measure and improve the processes that they are responsible for through standardisation, communication and automation (Porter, M.E., 2001).

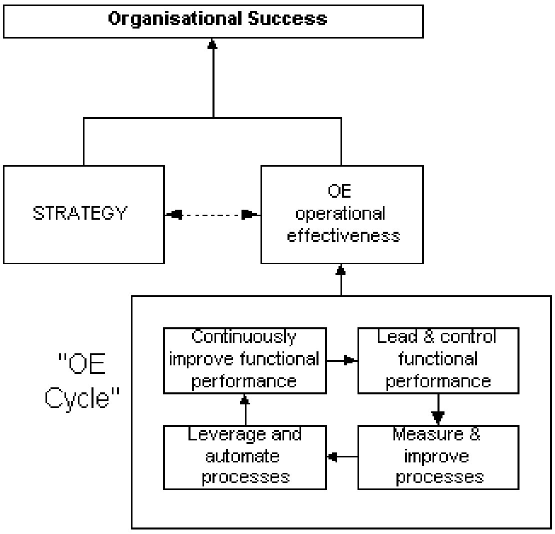


Figure 2.7: Operational Effectiveness cycle

Source: Porter, M.E., 2001

Operational management tools are used to measure and improve processes as well as to optimise processes through automation. There is a greater possibility of success if an automation is executed according to the overall process improvement strategy (Van Ewyk, O., 2003). By defining operational management tools, this section completes step 1.3.3.1 of the research goal.

2.6.2 Automated check weighing as an operational management tool

In a pack house, finished products are usually checked for quality and mass conformance by sampling, as stated in Section 2.3.1. Although this is sufficient for record keeping, defective products may still occur and go unnoticed by the internal quality controller. Also, in order to comply with the average mass system, all products need to be checked and be supported by a mass record, (refer to Section 2.2.3).

Total check weighing of the final product can be conducted by a person but, as shown in Section 2.5.3, humans are prone to error, especially in jobs with high stress levels. In an attempt to eliminate human error from the final quality checking process an operational management tool, like an automated check weighing system, could be used to perform the operation more efficiently and accurately.

Automated check weighers usually have two parts, as shown in Figure 2.8, the check weigher unit on the left and a faulty package separator unit on the right. The check weigher unit consists of a speed-up conveyor belt for speeding up the punnets fed by the packing line, a load cell and conveyor belt combination, as well as the check weigher controller and the display. This modular design allows the machine to be easily integrated into an existing production line (Saurin, T.A. *et al*., 2012). It also allows for keeping a record of product mass on a remote computer.

Figure 2.8: Automated external check weigher

Source: Guangdong HighDream, 2011

The average mass system requires any measuring or checking equipment to be able to determine the mass of a product to within one fifth of the Tolerable Negative Error (TNE). The use of less accurate equipment is not prohibited, but a higher target quantity will then be required, resulting in a give-away (United Kingdom Department for Innovation, Universities and Skills, 2007). Records of qualifying products' mass must also be kept. This adds to the requirements for automated check weighing in step 1.3.3.2 of the research goal.

Making use of an automated check weighing system for total final checking, instead of only random sampling, will enable a producer to pack to the average mass system and subsequently save on give-away. By removing the human error factor from the mass quality checking process, it may also increase the quality of the final product. Consequently, the mass quality control process will be promoted and the company's continuous improvement strategy kept on track. Together with its record keeping functionality, the check weigher offers a suitable solution for improvement in operational effectiveness in accordance with the long term strategy for process improvement for producing more punnets with less give-away.

2.7 Productivity

The table grape export supply chain is a complex combination and integration of stakeholders and role players, as shown in Section 2.3.1. Although exported products generate substantial income in the markets, only a very small amount reaches the farm gate. As shown in Figure 2.9 the net farm income is only half a percent of the gross income generated by exported table grapes (Greeff, P. and Kotzé, M., 2007). The rest is paid as monies for services and logistics, with the greatest expense being the production and packing of the grapes at the farm.

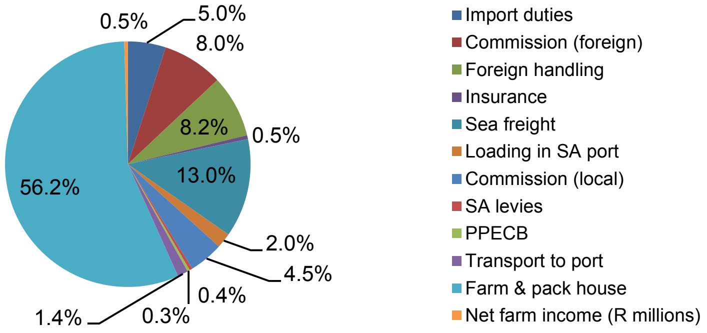


Figure 2.9: Distribution of costs incurred in export of South African table grapes, 2005 season

Source: Own graph created with data from Greeff, P. and Kotzé, M., 2007

Productivity at pack house level is therefore a key success factor if profitability is to be guaranteed. This section will discuss the measuring of productivity in the pack house.

Productivity could be measured in many different ways, refer to Section 2.1 but, because labour is one of a table grape producer's biggest expenses (Ntombela, S., 2010), it would be appropriate to depict the productivity of different packing systems in terms of the labour input. Literature defines labour productivity as the ratio between the volume measure of output and the measure of input used (Freeman, R., 2008; O'Mahony, M. and Timmer, P., 2009). The measure of output reflects the goods and services produced by the workforce and the measure of input use reflects the time, effort and skills of the workforce. Labour input is measured either by the total hours worked by all those employed or by total employment, with the former being the more appropriate measure of labour (Freeman, R., 2008; Feldstein, M. S., 1967).

The most appropriate measure of throughput productivity would thus be punnets per man-hour or the total punnets produced divided by the total hours worked by all those employed. The total number of workers used for the calculations includes cleaners, trimmers, punnet fillers, scale operators as well as workers who pack and wrap the boxes and those working in the pre-cooling and cold rooms (Jacobs, F.R. and Chase, R.B., 2011). This definition of productivity partly completes step 1.3.2.2 (Determine the productivity of current packing practices) of the research goal.

2.8 Conclusion

The literature review has provided a background to the table grape industry in South Africa, with special emphasis on punnet packing, which is the research topic. Available literature was found on the productivity of table grape punnet packing and the systems used, but it revealed a void in the measurement of packing system accuracy and error occurrence, thus providing an opportunity for this research to cover new ground.

The market research revealed that in the past the South African table grape export industry has seen steady growth in the traditional EU and UK markets, but during the last few years has been under constant pressure from the economic downturn, the stronger Rand-Pound and Rand-Euro exchange rates, stricter EU and UK import regulations and the growing supply from other Southern Hemisphere countries. Subsequently, there has been a visible shift towards emerging markets in the Far East and Asia, as well as the Middle East. The demand for pre-packaged fruit and vegetables in the EU and UK is at about 70% of the available fruit and vegetable rack space, but is reported to be fast approaching maturity. However the demand for pre-packaged table grapes in Eastern Europe and Asia is growing fast, as consumers are showing similar changes to those seen in Western Europe with regard to healthy living and product convenience.

Conforming to the average mass system allows a producer to produce and sell products of a nominal mass with a predetermined allowable negative tolerance, thus providing savings in the form of minimal product give-away. Conforming to the average system requires a producer to conduct final product check-weighing and to keep record of the product masses for reference.

South Africa is ranked among the top table grape exporters in the world, with its main competitor in the Southern Hemisphere being Chile. South Africa has the competitive advantage of being physically closer to the European markets, but research has shown South Africa to be less competitive than Chile because of factors such as the cost and the levels of skill of labour, as well as the cost of technology and the lack of timely and accurate feedback information.

Seasonal labourers often have only a limited formal education and are associated with many social problems that impair their ability to perform quality work. The human performance curve is used to describe work performance, where it is difficult to predict the optimal levels of stress and arousal at which labourers would perform best. Table grape producers have numerous programmes targeting social growth and providing job-specific training in order to improve opportunities for the labourers. These social growth programmes are usually in accordance with the requirements for quality and social accountability set by consumers.

Product quality is determined by consumers and measured by a number of attributes. These include physical attributes such as the taste, appearance and mass, as well as perceived attributes, such as the healthfulness and naturalness, the care taken with environmental considerations, the social accountability and convenience. These consumer requirements are incorporated into numerous standards, of which some are legally required and others are preferred by importers.

Despite incorporating the numerous consumer requirements, many of these standards also encourage or require continuous process improvement to ensure that the quality of produce keeps improving. Conformance to the physical quality aspects are confirmed by external Quality Standards Inspectors before a product leaves the pack house.

During production product quality is affected by human and machine errors. Operational management aims to reduce these operational effectiveness problems through continuous process improvement and by the use of operational management tools like automated check weighing. Operational management also aims to improve productivity by increasing the number of punnets produced per man-hour.

By providing the background to table grape punnet packing in South Africa, the first task towards accomplishing the research goal, Section 1.3.1 (Determine the state of table grape punnet packing in South Africa), has been completed via the literature study. Chapter 3 will complete step 1.3.2.1 (Find the packing technologies and practices used in the table grape punnet packing industry) and the rest will be completed by conducting a needs assessment survey, a productivity study and check weigher experiments, throughout the rest of the thesis.

3. Punnet packing systems

The basic method of punnet packing comprises a packer using a generic scale to produce punnets with the desired mass. As the packing process became more technology-driven, punnet packing technology evolved to systems that automatically combined the correct weight of bunches. Following the emergence of lean manufacturing principles in the punnet packing industry, the technology evolved back to its roots, with a packer being guided by a scale to produce punnets of the desired mass. During the course of this research project, punnet packing technologies from over the evolutionary timeline were encountered.

In this chapter the different punnet packing systems will be discussed using process flow diagrams, thus completing step 1.3.2.1 of the research goal. Systems are divided into two categories, namely those featuring built-in check weighing and those that do not. Figure 3.1 shows the symbols used in the process flow diagrams.

Figure 3.1: Symbols used in process flow diagrams

Source: Smit, R. *et al*., 2012

3.1 Punnet packing system: No internal check weighing

3.1.1 Generic scale system

The generic scale system is described in Figure 3.2. It is the most basic system and is often referred to as the guess-and-cut method because packers must guess the amount of berries to remove or add to achieve the desired punnet mass. This method does not include any technology supported built-in check weighing functionality and the only feedback is the mass displayed by the scale. Packers are instructed to conform to certain upper and lower mass limits and therefore some arithmetic is required. Labourers with a limited formal education may find it difficult to master this method. Studies have also pointed out that workers may find this method to be cognitively exhausting, because of the monotony of the task (Smit, L., 2008; Eichele, T. *et al*., 2008). Due to its labour intensiveness, the generic scale system requires intensive management to be employed successfully (Smit, R. *et al*., 2011).

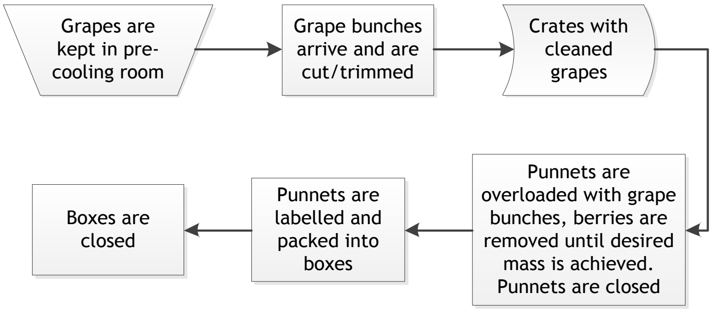


Figure 3.2: Generic scale system process flow diagram

Source: Smit, R. *et al*., 2012

3.1.2 Lane sorting assisted packing system

Figure 3.3 describes the lane sorting assisted packing system. This system has the lowest initial cost of all available machine aided systems. Packers at each station have pre-cut clippings within a mass range. A punnet is weighed and the scale indicates the appropriate lane for it to proceed to with clippings of the complementary mass to make up the correct punnet mass. The system does not include any type of check weighing as it merely assumes that all clippings are correct and that operators put the punnets in the correct lanes. This system is easier to master than the generic scale system, because labourers do not have to do as many calculations by themselves for the system to work.

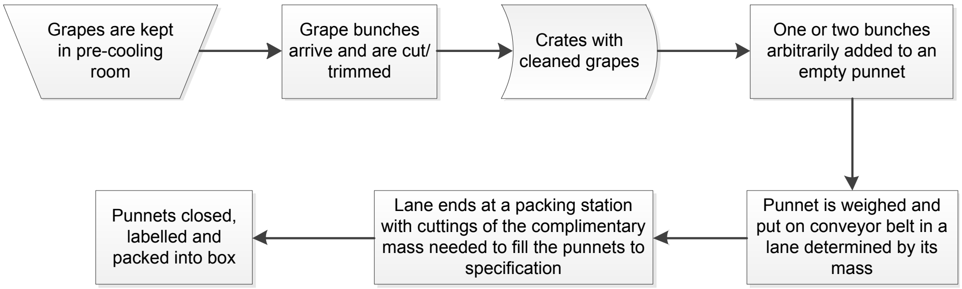


Figure 3.3: Lane sorting assisted packing system flow diagram

3.2 Punnet packing system: Internal check weighing

The punnet packing systems in this section all incorporate some type of internal check weighing to ensure conformance to punnet mass. However, these either rely on, or make, assumptions regarding the human operators and the dynamics of the grape supply, which makes them prone to errors (Pettersen, J., 2009).

The four systems described in this section all feature adjustable parameters for the upper and lower limits, as well as for a target mass. Each system aims to produce punnets with a mass as close to the target as possible. The local storage combination system, microcontroller-assisted scale system and computer-supported scale network system all feature dynamic target mass adjustment. The local storage combination system manipulates the mean punnet mass towards the target by dynamically adjusting the upper limit either upwards or downwards within the allowable band. The microcontroller-assisted scale system dynamically adjusts the lower limit as well as the target mass within the allowable band to manipulate the mean punnet mass towards the original target. The computer-supported scale network system dynamically adjusts the allowable band upwards or downwards within the absolute limits while keeping the target constant (Marco Ltd, 2011).

3.2.1 Local storage combination system

The local storage combination system comprises a vertical storage rack with a microcontroller-based scale on either side, integrated using common in-process storage (Koegelenberg, M., 2010). When a packer weighs a bunch, the scale checks for a complimentary bunch already on the rack to make up the desired weight. If a complement is found, the bunches are added together. If no compliment is found, the bunch is stored in an allocated position on the rack. The process flow for this system is described in Figure 3.4. For optimal operation the system requires three people on either side, who switch position throughout the day to cross-check each other's work (Smit, L., 2008).

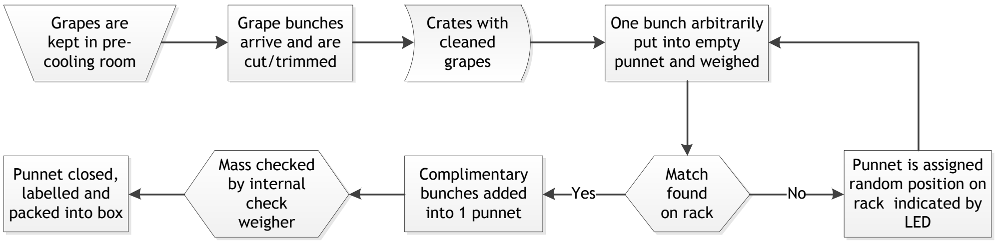


Figure 3.4: Local storage combination system process flow diagram

Source: Smit, R. *et al*., 2012

Literature suggests that errors are bound to occur due to the monotony of the task (Eichele, T. *et al*., 2008), creating the necessity for the possibility of human errors to be removed from the system (Pettersen, J., 2009). This system therefore features an internal poka-yoke (mistake-proofing) type error recognition system that is independent of lapses in the attention span of an operator (Saurin, T.A. *et al*., 2012) to recognise punnets of incorrect mass before the process has been completed (NKS, Ltd./Factory Magazine, 1988). After combining the complementary bunches into one punnet, the mass is verified by the internal check weighing function to be within specification and a green go-ahead light is displayed to the operator. In the end it is still dependant on the operator/packer to execute the task as instructed and human errors may still occur.

3.2.2 Conveyor combination system

The operation of the conveyor combination system is described in Figure 3.5 (Koegelenberg, M., 2010). It is a computerised horizontal conveyor combination system that runs at high speed and packers need to be alert so as not to miss a bunch or pick up the wrong bunch. Literature also suggests that bunches need to be cut to roughly half of the desired punnet mass for the system to work effectively (Cambray, G., 2007). The computer ensures that combinations are made within the allowable mass limits; the internal check weighing assumes that packers do not make mistakes and that no loose berries fall from bunches when picked up from the cups. There is no feedback from the check weighing function.

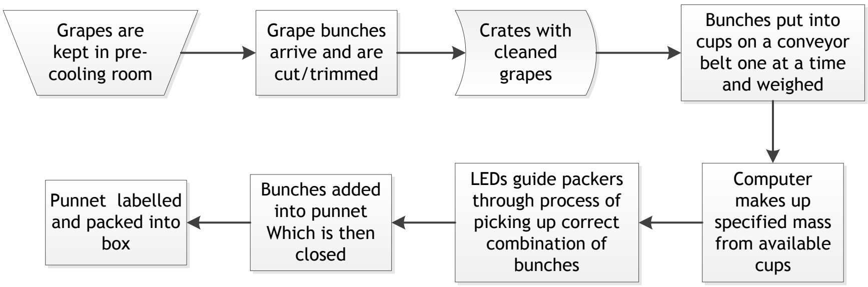


Figure 3.5: Conveyor combination system process flow diagram

Source: Smit, R. *et al*., 2012

3.2.3 Microcontroller-assisted scale system

The microcontroller-assisted scale system is a newly developed system and was first used during the 2011/2012 packing season. It is similar to the generic scale system, but packers are assisted by a microcontroller in achieving the correct punnet mass. The operation of this system is described in Figure 3.6. Each scale operator has to perform several tasks on the grapes, including cleaning out bad berries and sorting bunches by berry size, then filling a punnet to the approximate mass and correcting it using the microcontroller-assisted scale (Verwey, N. *et al*., 2012). The operation is not as monotonous as some other systems, hence reducing the occurrence of errors (Eichele, T. *et al*., 2008). The internal check weighing function forms part of the scale operation, as the microcontroller will guide the operator towards achieving the target mass; although any mass within the allowable limits is accepted.

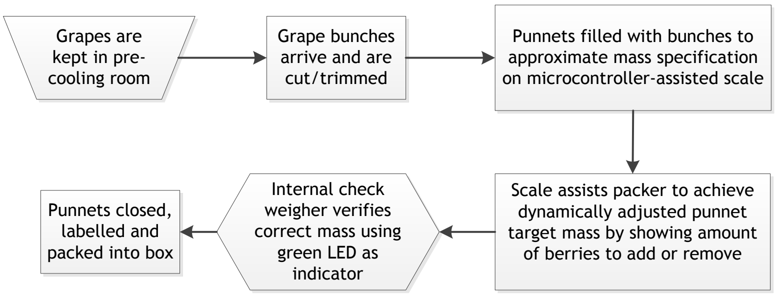


Figure 3.6: Microcontroller-assisted scale system process flow diagram

3.2.4 Computer-supported scale network system

Another new entry to the South African market is the computer-supported scale network system, also first used during the 2011/2012 season. It is a computer-based-scale assisted hand packing system featuring dynamic target mass adjustment. Its operation is described in Figure 3.7. The network computer dynamically adjusts the allowable bandwidth either upwards or downwards and assists the packers in achieving approximately the desired mass using LEDs. If a punnet is removed from a scale while the mass is outside the allowable bandwidth, the internal check weighing function locks the user interface and a supervisor code must be entered to resume operation.

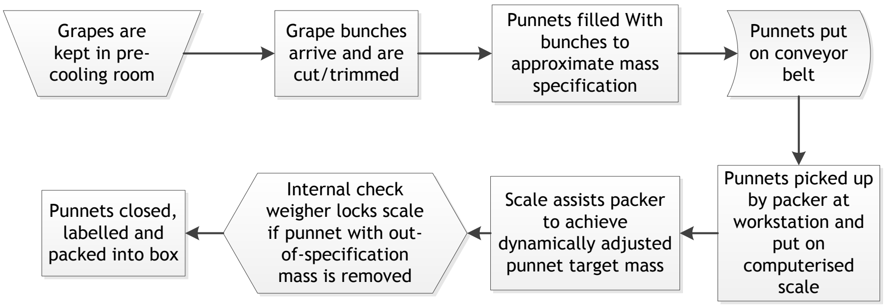


Figure 3.7: Computer-supported scale network system process flow diagram

Source: Smit, R. *et al*., 2012

3.3 Conclusion

For any application requirement, there exists an appropriate punnet packing system, be it a single punnet producing unit or a full-scale punnet producing scale network system. In an attempt to eliminate or reduce operator error, some punnet packing systems incorporate internal check weighing. However it is still up to the operator to make use of the functionality, which is often viewed as unnecessary and omitted.

This chapter completes step 1.3.2.1 of the research goal by identifying the different packing technologies and practices used in the table grape punnet packing industry.

4. Results: Needs assessment survey

At the end of the 2010/2011 table grape packing season a needs assessment survey was conducted among a randomly selected group of table grape producers and export companies using structured telephonic interviews. The questionnaire is given in Addendum C. The goal of the survey was to investigate different pack house situations. Collectively the selected group of producers accounted for 9% of South Africa's total table grape exports during the 2010/2011 season, with their punnets alone contributing 3% of the total exports.

Many of the results were presented at the ISEM 2011 conference (Smit, R. *et al*., 2011), but in this chapter all the results from the needs assessment survey will be presented and discussed at the necessary level of detail. Section 4.1 will create a profile of the parties interviewed, in terms of their size and the packing systems used. Section 4.2 discusses management strategies in terms of the operator/packer training provided for the different systems, how intensely the packing processes are managed during the season and the level of quality control applied. In Section 4.3 the application of quality control is discussed, first looking at the different quality standards applicable to producers, then discussing the inspection processes and, lastly, stating the reported occurrence of under mass punnets found during inspection. An economic analysis is conducted in Section 4.4, first looking at the possible penalties incurred for rejected pallets, both locally and internationally, and then calculating the payback period for check weigher implementation for any size producer using any pack house layout. Section 4.5 reflects on the needs mentioned by interviewees regarding the implementation of check weighing and the chapter is concluded in Section 4.6.

4.1 Profile

The survey was conducted among twenty producers representing all the table grape producing regions of South Africa. Most of these producers use both conventional and punnet packing methods. This section will create a profile of the diversity of the interviewed producers in terms of size and packing systems used.

4.1.1 Producer size

Producers of all sizes were interviewed during the survey. In order to determine the size of each producer, each had to state the number of punnets produced during the 2010/2011 packing season and the percentage of their total table grape production exported as punnets.

Producer sizes varied between 150 000 punnets and 2 700 00 punnets for the 2010/2011 packing season. The producer size distribution is shown in Figure 4.1. Sixty percent were producers with a total punnet production of up to 500 000 during the season. Most small producers produced all their punnets at one location, while some of the larger producers had numerous pack house locations for producing their punnets.

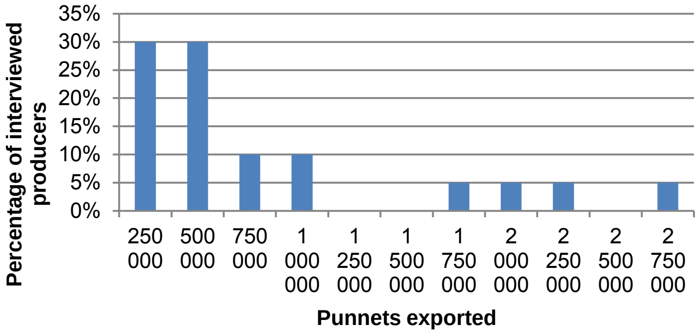


Figure 4.1: Total punnets produced during 2010/2011 packing season

In an interview the PPECB, a statutory organisation controlling all perishable exports from South Africa (PPECB, 2011), stated that only 60% of table grape producers in South Africa produce punnets. The results from the interviews are summarised in Figure 4.2. Three quarters of the producers interviewed exported between 20% and 50% of their table grapes in punnets, with only 15% exporting more than 50% in punnets.

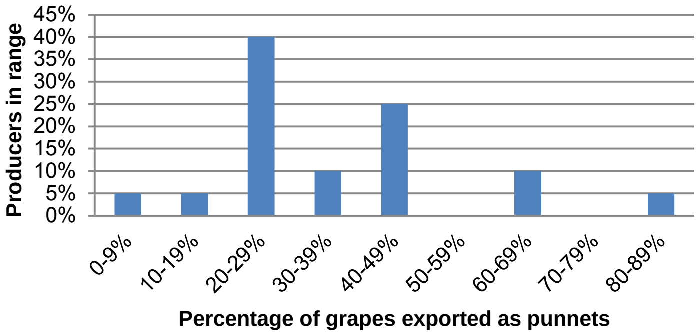


Figure 4.2: Percentage of total table grape production exported in punnets

Source: Smit, R. *et al.*, 2011

The results show that producers are reluctant to use punnets for packing, particularly when compared to the French CTIFL study reporting 70% pre-packaging (Refer Section 2.2.2). In an interview one export company predicted a demand for 80% of grapes to be packed in punnets in the near future. Possible reasons for the reluctance include the labour intensity of punnet packing, the higher cost of packing material and the complexity of the packing method (Koegelenberg, M., 2010).

4.1.2 Packing systems used

In Chapter 3 six different punnet packing systems were described. Of these six systems, two were new, first used during the 2011/2012 packing season. This survey covered only the four systems available during the 2010/2011 season. The different systems used by the producers interviewed are depicted in Figure 4.3.

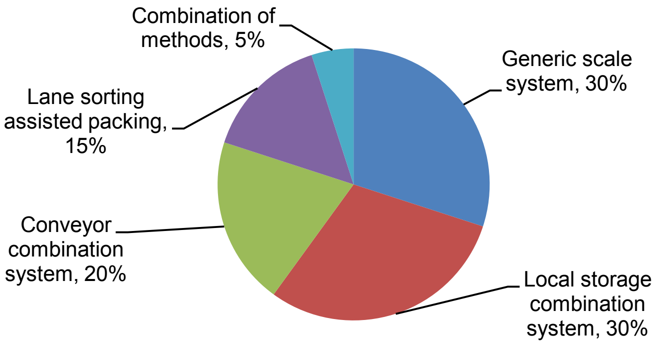


Figure 4.3: Packing systems used by producers interviewed

Source: Smit, R. *et al.*, 2011

The generic scale and local storage combination systems were the most used. The generic scale system is the most basic system, available at the lowest cost. This indicates the reluctance of producers to invest capital in technological solutions to help improve punnet production. The conveyor combination system is much more expensive than the local storage combination system, which renders it less popular. Only 5% used a combination of systems, indicating that producers tend to stick with one system when they find it meets all or most of their requirements.

In this section a profile of the producers interviewed has been created in terms of production size, the ratio of punnets to conventional packing and the packing systems used. The next section will discuss different management strategies and how they are implemented.

4.2 Management strategy

Management is defined in the Dictionary of Health Education as the process of organising, coordinating, directing, evaluating and utilising human and financial resources to achieve the objectives of an organisation (Bedworth, D.E. and Bedworth, A.E., 2010). Strategy is defined by the same dictionary as a combination of methods planned to complement, supplement and reinforce each other to reach long-range objectives. For the grape packing industry a management strategy would thus refer to a producer's process of training and managing its human resources, in combination with its quality control procedures, to achieve its objective of producing high quality products.

In this section the different management strategies employed by producers for different packing systems will be discussed in terms of the level of training given to system operators and packers, the intensity with which the systems are managed and the level of quality control enforcement employed for each system. Each aspect is rated as having a low, medium or high level of intensity.

During the interviews producers were asked to choose the description best suited to their specific punnet packer training strategy. The options were: No training provided (Low level); all packers and operators receive on-the-job training only (Medium level); all packers and operators receive training beforehand and on-the-job (High level). A summary of the results is shown in the second column of Table 4.1.

Table 4.1: Punnet production management strategy

Packing system	**Packer training**			**Management intensity**			**Quality control**		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Generic scale system		11%	21%	5%	21%	5%		26%	5%
Lane sorting assisted packing			16%		5%	11%	5%	11%	
Local storage combination system		21%	11%	5%	21%	5%		32%	
Conveyor combination system		5%	11%			16%		16%	
Combination of methods			5%			5%		5%	

All producers reported providing medium to high levels of training, with the majority reporting a high level of training. The local storage combination system was the only one with a majority providing a medium level of training. One interviewee described the local storage system as a game of which the skill is best learned while playing it. This explains why producers using this system tend to provide on-the-job training only.

Most producers reported that between 50% and 80% of seasonal workers return year after year. This reduces the amount of training needed and the returning workers can often assist in training new workers on-the-job.

The management intensity was also determined by asking producers to choose the best suited description of their strategy. The following options were available: Only a single manager is appointed over the punnet section (Low intensity); a supervisor is appointed over every punnet line (Medium intensity); each packing line is divided into teams of packers with team leaders (High intensity). A summary of the results is shown in the third column of Table 4.1.

For the generic scale and local storage combination systems, equal number of producers reported low and high management intensities, with the mode being at medium. Users of the other systems mainly reported high management intensity. This difference in strategy could be explained by looking at the different system infrastructures and the definition of a punnet line. With the generic scale system all the scales are usually next to each other and form part of a single punnet line and therefore one supervisor over the punnet line would be sufficient. Similarly a few local storage combination systems in a cluster would form a punnet line and one supervisor over the line would be sufficient. The lane sorting assisted packing and conveyor combination systems are usually split into two sections or packing lines along the length of the system. This would make it difficult for one supervisor to tend to all packing stations and a team leader would usually be appointed for either side in conjunction with the punnet line supervisor.

Quality control is performed at two stages, by the internal quality controller during the packing process before the punnets are palletised and later by an external Quality Standards Inspector who draws samples from finished pallets. For determining the level of quality control, producers were first asked whether they performed internal quality control at all. If they did, they had to describe how often it was performed and how intensely. The following three levels were distinguished from the results: No internal quality control is performed (Low level); there is a quality controller stationed at each punnet line, doing spot checks (Medium level); each punnet is check weighed individually (High level). Column four of Table 4.1 summarises the results of the survey.

Most producers reported a medium level of quality control. Only one reported a high and another a low level of quality control. Interestingly, these were two of the most effective producers regarding under mass quality problems, despite their very different quality control strategies. One small producer used a generic scale system and reported giving a high level of packer training, with one supervisor over the punnet line who had to report to the manager of the punnet division. By having a quality controller check and weigh every single punnet again before they were palletised, they successfully eliminated all under mass punnets and were able to maintain a mere 15 g variation in punnet mass. The other producer, also small, used a lane sorting assisted packing system. He provided a high level of training to the packers by training them to work systematically and organise their packing tables, he increased the mean punnet mass by 20 g and also managed the punnet packing process very intensely and, by doing this, eliminated the need to perform any internal quality control at all.

An aspect not explicitly investigated by the survey, but implied by the results of Table 4.1, is the managing of financial resources in order to reach the goal of producing high quality products. Training, management and quality control are all financial burdens and producers attempt to save where they can. Each extra level of management adds extra salaries to be paid. If a producer realises unnecessary redundancy in their management strategy, they will aim to remove it, as with the generic scale and local storage combination systems. The same applies to quality control. Performing 100% check weighing using manual labour may require more than one person, depending on the production rate. The check weigher(s) must be employed in addition to a normal quality controller who checks for other quality aspects of the grapes. Most producers elect to have the normal quality controller perform only random spot checks on punnets and check for mass conformity as well.

As seen from the survey results, there are many ways of effectively managing punnet packing, each with its own pros and cons. Increasing the punnet mass to eliminate quality control reduces the amount of labour needed, but results in financial losses due to giveaway. On the other hand, increasing the management intensity and level of quality control adds more labour, but saves on giveaway. The bottom line as gained from these results, is that each producer manages their system in a unique way suited to their specific needs and setup.

4.3 Quality control

Quality specifications for produce are determined by the applicable quality standards. As was the conclusion in Section 4.2, producers have different ways of ensuring adherence to these quality specifications, including quality inspection. From this follows that the occurrence of under mass punnets during inspection may be used as a parameter of verification as to the effectiveness of different quality strategies.

4.3.1 Standards

Different quality control standards applicable to the table grape industry were discussed in Section 2.5.2. Figure 4.4 depicts the most common quality control standards and the percentage of the producers interviewed that they apply to. The PPECB standard is the minimum quality standard and is applicable to all perishable product exports from South Africa, and therefore all producers must adhere to it.

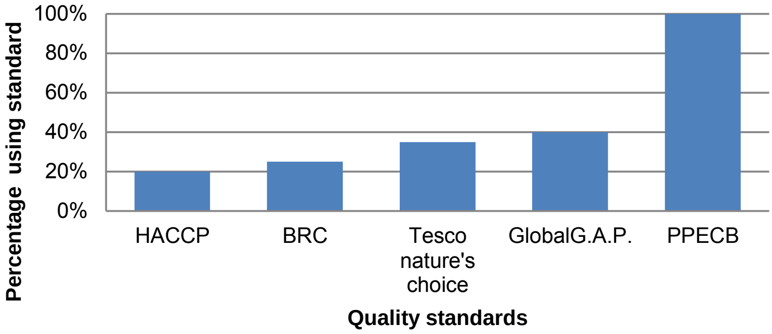


Figure 4.4: Quality standards used by producers

Source: Smit, R. *et al*., 2011

The PPECB standard is continuously enforced during the season by Quality Standards Inspectors, while the other standards provide guidelines for product quality. Before the commencement of the packing season, and sometime during it, inspectors for the other standards like HACCP, BRC and GlobalG.A.P. may perform unannounced inspections of the pack houses and award or revoke accreditations for the specific standard.

4.3.2 Inspection

In Section 4.2 it is stated that quality control via product inspection is performed at two stages: By the internal quality controller during the packing process before the punnets are palletised and later by an external Quality Standards Inspector, after drawing samples from finished pallets. In the survey producers were asked to describe how internal and external quality control was implemented at their pack houses. The results, as presented at the ISEM 2011 conference, (Smit, R. *et al*., 2011), are discussed in this section.

Internal quality control:

In a pack house the quality management is performed by a quality controller (QC). The QCs are normally trained by the producers, but in some cases QC training is performed by the export companies. A QC's role is to constantly monitor product quality at different steps during the production process. Among other quality factors, they check the finalised punnets for correct mass. Any quality problems arising during the inspections are documented and the QC must try to correct them. If a problem persists, it needs to be reported to the punnet line manager. Most pack houses incorporate well developed traceability practices and any deviance from the quality standard can be traced back to a person or packing station.

Quality inspection is done by randomly selecting cartons from the production lines and checking the content for certain quality factors, including the correct mass. The survey reported that on average between 1% and 10% of cartons are checked, except for one producer who reported checking 100% of the punnets. If problems are discovered, they are traced back to the source and corrective action is taken.

External quality control:

The PPECB performs mandatory external quality control using its own Quality Standards Inspectors. Quality inspectors from the exporting companies or the clients also perform occasional inspections during the season. Inspectors from PPECB are required to inspect at least 2% of all the exported cartons. Cartons are arbitrarily chosen from finished pallets and the contents are checked for quality adherence. Among other quality factors, the punnets are also checked for the correct mass. If a defect is detected, more random samples are taken from the pallet and checked for quality. If more defects are discovered from the same pallet, all the punnets from that pallet must be checked and repacked where necessary. If no more defects are discovered, the pack house only receives a warning, however some clients enforce a zero tolerance policy and upon discovering a single defect, all punnets have to be checked.

External quality control reflects the effectiveness of internal quality control. Where a producer has implemented good internal quality control and rather intensive management, few to no pallets were rejected by external Quality Standards Inspectors. In addition to the pack houses, external quality control checks are also performed at the ports prior to shipping and upon arrival overseas.

4.3.3 Under mass detection frequency

In the survey producers had to state the frequency of occurrence of under mass punnets. The reported results for both internal and external quality control are summarised in Figure 4.5.

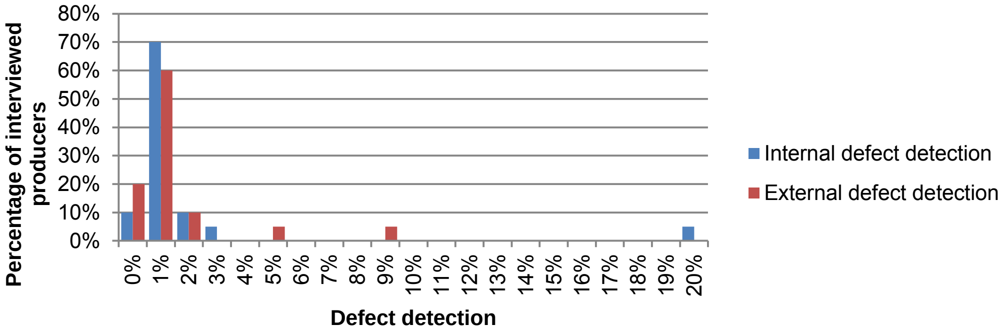


Figure 4.5: Occurrence of mass errors during inspection

During internal quality control an average of up to 3% of the samples were found to be under mass when packing was done by hand or using the lane sorting system. During a personal interview, a QC revealed the frequency of under mass punnet detection during internal quality control inspections to be about 20% when packing by hand. This was inconsistent with the 1% detection stated by the production manager for the same producer. The results presentation, (Smit, R. *et al*., 2011), raised a concern that, in general, where management and the QCs are not working closely together, management tends to be ill informed regarding problems and that this could be attributed either to the ‘nobody wants to be a bearer of bad news’ syndrome or to the fact that either the QCs or management wanted situations that were difficult to manage to appear less severe.

If this is correct, the actual number of under mass punnets found during internal quality inspections could be higher than originally stated. The conveyor combination and local storage combination systems reported a high occurrence of under mass defects in the beginning, which later reduced to the order of 1% as the packers became more experienced.

The reported frequencies of under mass detection during external quality inspections varied between zero and 8,5%. The PPECB stated in an interview that 5,7% of all inspected table grape products were found to be under mass during pack house inspections. Since this is higher than the percentage stated for internal inspections, it could indicate the need for better internal quality control. The table grape exporting company, Capespan, reported that less than 1% of their exported pallets were rejected overseas due to under mass punnets, indicating efficient external quality control.

In this section the focus was on partly completing step 1.3.2.4 of the research goal by determining the statistical parameters of under mass punnet occurrence as well as describing the quality control processes implemented for partially completing step 1.3.2.5 of the research goal.

4.4 Economic analysis

Following the results obtained from Section 4.3.3, this section will summarise the actions to be taken upon pallet rejection at different stages along the supply chain, as recorded during the survey. A financial cost factor will be added as well, from the survey.

In the second part of this section a payback period calculation based on potential savings will be done for implementing the external check weigher from Section 2.6.2.

4.4.1 Penalty for rejected pallets

Producers taking part in the survey were asked to describe the steps of action to be taken for pallets rejected at different stages along the logistics chain. The results, as presented at the ISEM 2011 conference, (Smit, R. *et al*., 2011), are discussed in this section. The second part of step 1.3.2.4 of the research goal is to determine the financial implications of under mass punnets, and will be completed in this section.

When a typical pallet of 1150 punnets is rejected at the pack house, all the punnets need to be checked for quality and repacked if necessary. Usually the packing line responsible for producing the pallet also has to repack it. This consumes a lot of time and results in the loss of production. Defective punnets also require new packaging material. The physical cost of repacking a pallet was estimated between R200 and R800. When adding the loss of potential production of another pallet, the amount may rise to as high as R10 000, as shown in Figure 4.6. Pallets rejected at a pack house for quality defects other than mass are sent to alternative markets using lower quality standards, rather than repacked.

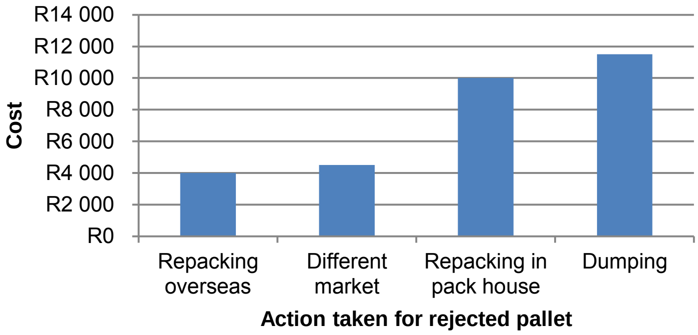


Figure 4.6: Cost of different actions taken when pallets are rejected

Source: Smit, R. *et al*., 2011

If pallets are rejected at a local port, they are rather sold to the local market, at a considerable loss, than repacked. If a rejection occurs overseas, there are a few options: The pallet could be sold to a different market at a revenue loss of about R4 500. Alternatively, a pallet could be repacked at a cost of R30 to R40 per carton or about R4 000 per pallet. If the quality cannot be restored by repacking, the pallet must be dumped, at an approximate cost of R20 per carton plus R80 lost income per carton, or R11 500 per pallet. These alternatives are also shown in Figure 4.6. In addition, producers may also run the risk of losing contracts due to frequent quality defects. Mass is regarded as a very important quality attribute (Verwey, N. *et al*., 2012).

Over mass packing was revealed by the survey as a less obvious, but serious, problem during production. A giveaway of 10% per punnet, equates to one carton lost for every ten packed and adds up to more than R1 000 per pallet. Overfilled punnets may also encounter quality problems, because the contents may bruise more easily during handling.

4.4.2 Check weigher payback period

In Section 4.3.3 it was shown that under mass punnets do occur, and that they have resulted in pallets being rejected both at pack house level and overseas. These rejections can be very costly, as discussed in Section 4.4.1. One producer had shown that 100% check weighing of punnets could eliminate the risk of pallet rejection due to under mass punnets. Despite this fact producers are unwilling to implement final check weighing in their pack houses due to the labour intensity. A possible alternative would be an automated final check weigher, which leaves the normal QCs to go about their jobs and concentrate more on other quality factors. To ensure that a producer would benefit from this solution, a financial analysis would have to be done, considering the producer’s specific size and pack house configuration.

A check weigher cannot generate income for a producer, but it can reduce potential losses by reducing the risk of pallet rejection. The check weigher payback period calculation is very straightforward: the time it would take the check weigher to produce its initial value in potential savings of rejected pallets without considering the time value of money.

For the calculation the occurrence of under mass punnets was taken at 1%, as found in Section 4.3.3 and the cost of a rejected pallet at the pack house was taken as R10 000, from Section 4.4.1. Without modification, a check weigher can service only a single punnet line. Producers in the survey were asked to indicate the number of punnet lines per pack house. The owner of Wespak Manufacturing, an installer of pack house equipment, quoted the price of an automated check weigher as R90 000 (De Jongh, J., 2011).

Figure 4.7 can be used to determine the payback period in years for a specific producer given the size (number of punnets produced) and the number of punnet lines per pack house. According to Dr Willem Barnard, Former CEO: KWV, in a Strategic Management lecture presented at Stellenbosch University in February 2011, the half-life of mechanical technology, in accounting terms, is no more than five years (Barnard, W., 2011). The check weigher payback period calculator, Figure 4.7, is divided into 2-year intervals. It is used to calculate the payback period in years, given the number of punnets produced, as well as the number of packing lines (or check weighers) used.

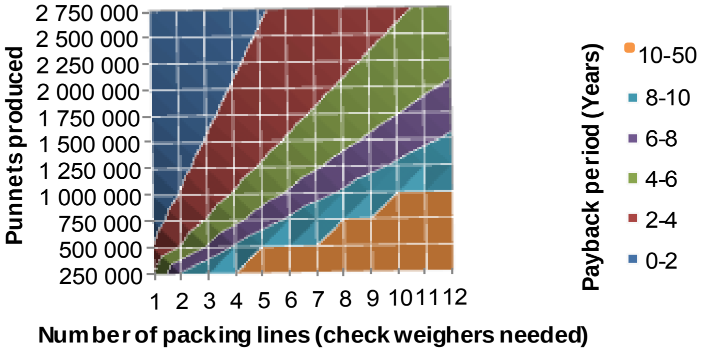


Figure 4.7: Check weigher payback period calculator

From Figure 4.7 it is clear that check weighers would be more viable for bigger producers in terms of a technology investment than for smaller producers. By determining the financial implications of implementing check weighing, this section completes step 1.3.2.4 of the research objective.

Figure 4.8 sorts the interviewed producers according to their size and number of packing lines. Most small producers (less than 500 000 punnets) have one or two packing lines. For these producers the payback period of one check weigher may be acceptable if no more than five years, but adding two check weighers would be out of the question.

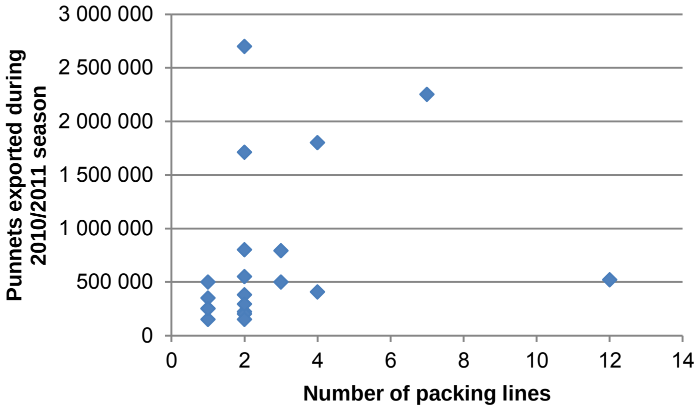


Figure 4.8: Number of punnet packing lines per producer size from survey

This section has shown that rejected pallets may cause very high penalties. This risk could be reduced by adding final check weighing. A costing analysis was therefore performed for implementation by different size producers, thereby completing step 1.3.3.5 of the research goal.

4.5 Demand for check weigher

At the end of the survey producers were asked whether they thought they could benefit from an external check weigher and to comment on their answers. The results are shown in Figure 4.9 and the comments will be discussed below.

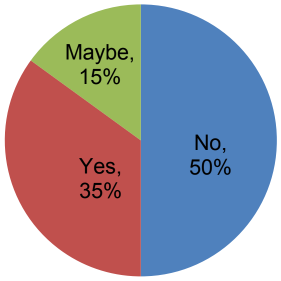


Figure 4.9: Survey check weigher demand results

Half of the producers interviewed said they would not benefit from an external check weigher. Many reported that they already performed final check weighing on all cartons before packing them onto the pallets, ensuring that a carton of ten punnets had a mass of at least 5,2kg. Others argued that they would have to make too many changes to their current setup in order to integrate an external check weigher, but that it would be good to implement check weighing from the start. One producer recalled having had such a system and that it used to cause a bottleneck. A small producer said he had too few problems to justify an expensive check weighing system. Some also argued that their current systems were effective enough to not need additional check weighing.

35% replied that they could indeed benefit from an external check weigher even though they would have to adapt their current setups. Adding automated check weighing would replace two to three labourers. If it could detect and remove over mass punnets as well, the check weigher could save thousands in giveaway.

15% were indecisive and reasoned that they actually just needed a system to keep log of punnet weights, as one producer already had a check weighing system. Two others commented that their punnet packing systems could be improved by adding check weighers, but were reluctant to do this because they did not want to change their current setup.

4.6 Conclusions

This needs assessment survey was conducted after the 2010/2011 packing season among randomly selected table grape producers throughout South Africa. It revealed that the majority of producers interviewed are exporting between 20% and 50% of their total table grape harvest as pre-packaged punnets. This indicates a reluctance to produce punnets, as compared to a French study reporting a need for 70% pre-packaged grapes and an exporter predicting a demand for 80% pre-packaged fruit in the UK and EU. This reluctance was also visible in the packing technologies used, with 30% still using the most basic generic scale system for packing table grapes into punnets, while other technology supported systems are available to increase productivity and incorporate internal quality control. The reluctance could be increased by the intimidating nature of punnet packing (labour intensity, higher cost of packaging material and complexity of the packing method).

Producers employed different strategies for providing packer training, managing the punnet production lines and conducting quality control. Most reported medium to high levels for all three areas. The survey revealed that two completely different strategies both had the same end result of superior product quality. By conducting total final product check weighing, one producer had eliminated the occurrence of under mass punnets and by increasing the mean punnet mass another eliminated the need for conducting check weighing at all; we see, therefore, that different strategies can work for different producers, to deliver the same result.

Product quality is determined by different quality standards, with the mix of standards which must be adhered to depending on the customer. In most cases an internal QC performs preventative quality checks via random punnet sampling, but some small producers report conducting total final product check weighing. Any problems are traced back and rectified. Before pallets leave the pack house, an external QC also performs quality checks on randomly chosen punnets from the pallet to verify conformance to the quality standards. On average, the internal inspections found up to 3% punnets under mass, while the inspections by external QCs found 5,7% of all checked punnets to be under mass at the pack house. 1% of exported pallets were rejected overseas due to the occurrence of under mass punnets.

The penalty for rejected pallets may be very high and cause a lot of unnecessary administration. By adding external check weighing, the risk of pallets being rejected due to the detection of under mass punnets could be greatly reduced. Using this risk reduction, together with the penalty cost of rejected pallets, the payback period for adding check weighers to any size producer with any layout was depicted on a sliding scale. This showed that check weighing would be viable for small producers with only one packing line, however many of the small producers interviewed had more than one packing line, making it very costly to implement check weighing.

The general feeling among producers is that the addition of check weighing would be too costly and disruptive to their current packing systems to implement, although they do recognise the potential savings attainable through detection of under mass punnets, as well as the reduction in give-away. Many, however, argue that their current systems are already effective enough. This presents an opportunity for accurately determining the occurrence of under mass errors in punnet packing.

In progressing towards accomplishing the research goal, the needs assessment survey determined the expected occurrence of under mass punnets and the financial impacts of the resulting pallet rejections (step 1.3.2.4); determined how conventional quality control is conducted and whether a technological solution such as automated check weighing could improve it (step 1.3.2.5); and performed a costing analysis for implementing an automated check weighing system (step 1.3.3.5).

In the next chapter the productivity of different punnet packing systems will be determined, together with the true occurrence of under mass punnets. Check weighing will also be evaluated as a tool for effectively removing under mass punnets.

5. Results: Productivity study

Part of the research goal is to determine the operational effectiveness of current packing practices. The needs assessment survey conducted, as reported in Chapter 4 provided only estimated values for some operational effectiveness parameters, providing an opportunity for this empirical study of operational effectiveness to be conducted as well.

During the 2011/2012 table grape packing season five types of systems used for packing table grapes were evaluated at one producer’s pack houses along the Orange River valley in the Northern Cape Province of South Africa. The five systems will be introduced in Section 5.1, in Section 5.2 the systems will be evaluated in terms of throughput, looking at capacity and productivity. In Section 5.3 system accuracy will be evaluated in terms of punnet mass distribution and giveaway. Comparisons with mass data from the company’s UK operation for the 2010/2011 and the 2011/2012 packing seasons will be used in Section 5.4 to investigate the effect of added check weighing. The chapter will be concluded in Section 5.5.

5.1 Punnet packing systems

This study included five of the six punnet packing systems described in Chapter 3. In some cases different installations of the same packing system was evaluated in the study at different pack houses. Three of the five packing systems were existing systems, as described in Chapter 3, with external check weighing added just before the 2011/2012 packing season. The other two systems were newly installed before the 2011/2012 packing season, and were also described in Chapter 3. One of the new systems featured both internal and external check weighing, while the other only had internal check weighing. Internal check weighing refers to the ability of a punnet packing system to check weigh punnets using internal functionality, while external check weighing refers to the ability to check weigh finished punnets independently of the packing system by means of an additional automated external check weighing module. Table 5.1 gives a summary of the five systems included in the productivity study.

Table 5.1: Punnet packing systems implementation for 2011/2012 packing season

Punnet packing system	State of system	Internal check weighing capability	External check weighing module added
Generic scale system	Existing system	No	Yes
Local storage combination system	Existing system	Yes	Yes
Conveyor combination system	Existing system	Yes	Yes
Microcontroller-assisted scale system	New system	Yes	Yes
Computer-supported scale network system	New system	Yes	No

Source: Adapted from Smit, R. *et al*., 2012

5.2 Throughput

In order to compare the throughput for the different systems, various factors had to be taken into account: Firstly, the physical size of the system was important because various different pack houses had similar systems, but with different physical sizes and hence capacity; the second factor to be taken into account, was the amount of labour needed to run each system; thirdly the number of working hours per day had to be considered. The last two factors are used by the producer to measure productivity in punnets packed per man-hour, refer to Section 2.7.

5.2.1 Capacity

The capacity of each system was calculated as punnets produced per hour calculated from the check weigher records. As mentioned earlier, this is not an effective way of comparing different packing systems, as it is dependent on the size of each pack house;

however, it does provide an idea of the capacity to be accommodated by an automated external check weigher, which forms part of the requirements for automated check weighing (step 1.3.3.2 of the research study). The punnets per hour capacities of the various systems are shown in Figure 5.1, the average and maximum values represent the duration of the study. Where more than one instance of a specific system was evaluated, the capacity of only the largest one is represented in the figure.

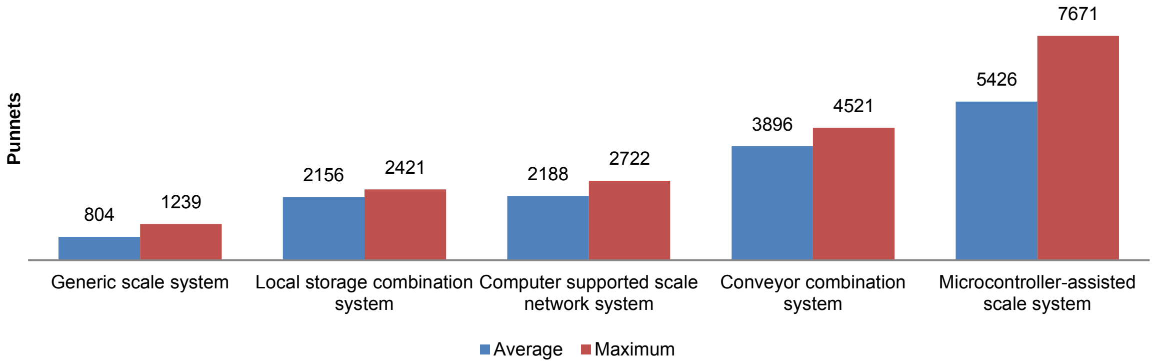


Figure 5.1: Punnets produced per hour for each packing system

In order to normalise system capacity to be applicable to any size of a specific system, the smallest operational unit was identified for each system: For the generic and microcontroller-assisted scale systems, the smallest operational unit would be one scale; for the conveyor combination system, the smallest operational unit would comprise the conveyor system with only one workstation position enabled; the computer-supported scale network system would also be operational with only one workstation scale enabled on the network; the local storage combination system is a modular system and the smallest operational unit would comprise one vertical storage rack with a scale on either side, requiring six people.

Figure 5.2 represents the average number of punnets packed per hour normalised to the smallest operational unit of each packing system. Depicting the capacity data in this way allows for easy calculation of the capacity that can be accommodated given a specific system or combination of systems and a specific size.

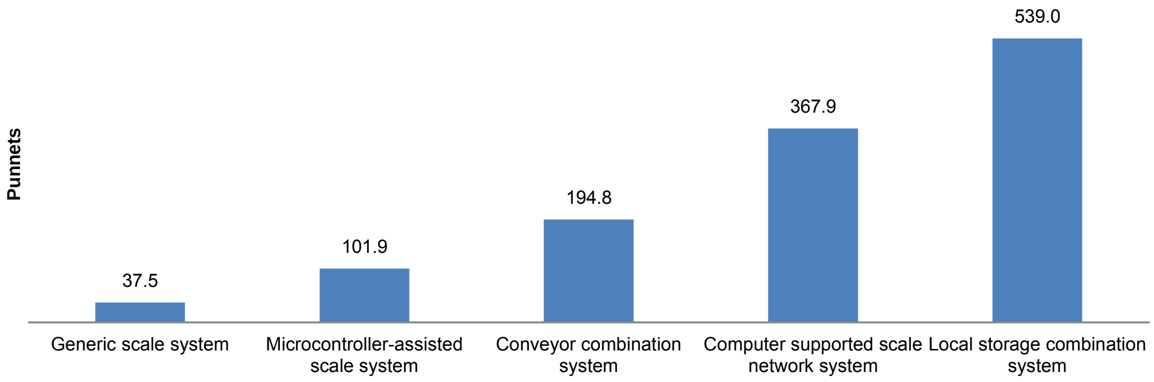


Figure 5.2: Punnets produced per hour per smallest operational unit of a packing system

5.2.2 Productivity

Productivity, measured in punnets per man-hour, is a very important parameter for the producer as it is used to compare the different pack houses on a normalised basis.

For calculating the daily punnets per man-hour ratio, the numerator was the total punnets produced per day and the denominator the total hours worked by all those employed at the pack house. Figure 5.3 gives the average ratio of punnets per man-hour for the duration of the study. The particular company had a daily target productivity ratio of 30 punnets per man-hour. As incentive, if the target was met, the pack house qualified for a payment bonus and if it was exceeded, the bonus increased accordingly. The computer-supported scale network, microcontroller-assisted scale and local storage combination systems are all based on lean manufacturing principles and use the minimum amount of people (Andersson, R. *et al*., 2006). The generic scale system uses lean principles as well, but it has a low output and more time is needed to produce punnets. The conveyor combination system is more labour intensive than the other systems and even when it is not operating at or near full capacity, it still requires a large amount of staff to be operational.

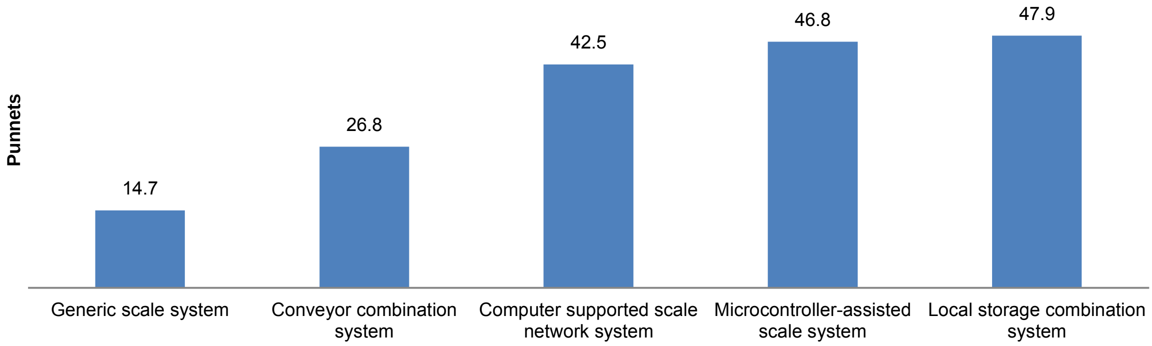


Figure 5.3: Punnets produced per man-hour

Figure 5.3 gives the productivity of current packing practices, completing step 1.3.2.2 of the research goal. With the cost of labour ever rising, companies need to increase their productivity in order to remain competitive in the global market (Mathekga, M. J., 2009). Producers often make use of seasonal labour from outside the area and need to provide housing, food etc. The trend is shifting towards employing fewer labourers who are more productive, and paid more as performance bonuses. This reduces the cost of housing and feeding.

5.3 Packing system accuracy

When considering packing systems, accuracy may refer to various aspects of the quality of the packed grapes. The focus of this thesis is mainly on the quality of mass accuracy and therefore only two aspects will be investigated in order to complete step 1.3.2.3 of the research goal (Determine the accuracy of current packing practices) (Gitlow, H.S. *et al*., 2005): The distribution of punnet mass and the amount of giveaway per punnet.

In this section the data collected during the 2011/2012 packing season for the five packing systems described in Section 5.1 will be discussed.

5.3.1 Punnet mass distribution

One average day of operation was chosen to represent each of the five packing systems in this comparison. For the generic scale system, local storage combination system and conveyor combination system, individual punnet mass data was collected by means of collating the check weigher data. For the microcontroller-assisted scale system and computer-supported scale network system, individual punnet mass data was not available; however, the average punnet mass as well as standard deviation was retrieved from both systems' daily computer logs. The data collected and analysed for this comparison spanned 90 063 punnets of grapes.

The punnet mass distribution for the generic scale system is shown in Figure 5.4. The distribution is skewed towards the upper limit, presenting an intuitive tendency to increased giveaway (Smit, R. *et al*., 2012).

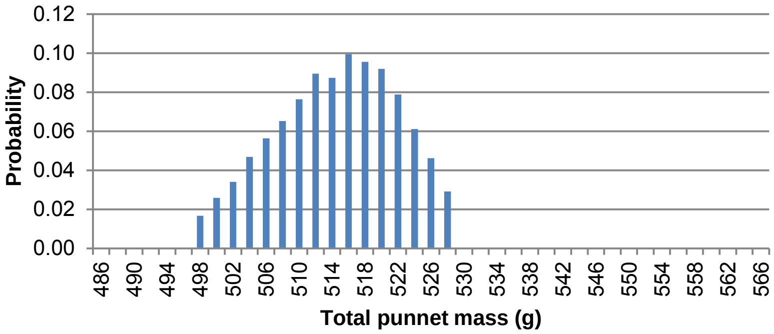


Figure 5.4: Generic scale system punnet net mass distribution

Source: Smit, R. *et al*., 2012

As shown in Figure 5.5, the local storage combination system's mass distribution is skewed towards the lower limit. This is a result of the target mass function and should have a positive influence on giveaway (Smit, R. *et al*., 2012).

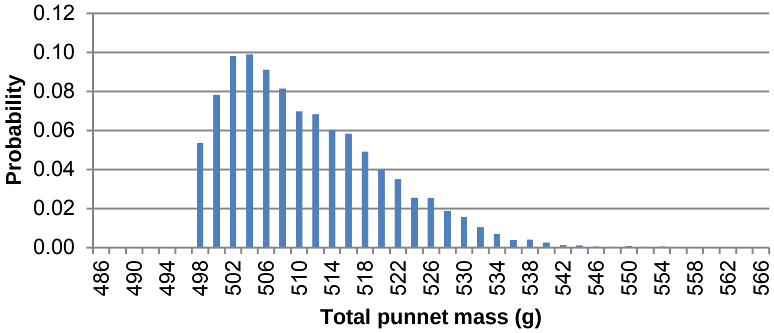


Figure 5.5: Local storage combination system punnet net mass distribution

Source: Smit, R. *et al*., 2012

Figure 5.6 shows that the conveyor combination system's distribution is skewed towards the lower limit as well. However, it has a relatively wider distribution than the other systems in the comparison, with a distinct tail towards the upper limit (Smit, R. *et al*., 2012).

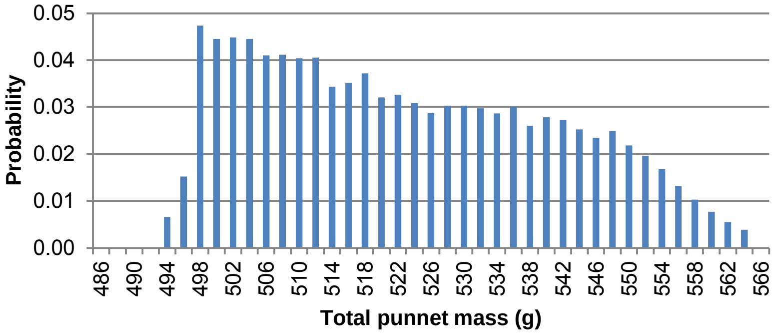


Figure 5.6: Conveyor combination system punnet net mass distribution

Source: Smit, R. *et al*., 2012

The mass distribution when using the generic scale system is shown in Figure 5.4. The results are shown in Table 5.2. Clear cut tails could be seen at 498 g and 528 g. These correspond to the upper and lower mass limits of the external check weigher. Although the packers were instructed to use the same limits as the check weigher, 10,3% of the punnets packed during the day were rejected at the external check weigher due to mass defects (Smit, R. *et al*., 2012).

Table 5.2: Punnet packing systems' operational results for an average day

Punnet packing system	Mean (g)	Standard deviation (g)	Mode (g)	Punnets packed	Punnets rejected on mass (%)
Generic scale system	513,3	7,2	515	13 042	10,3
Local storage combination system	509,8	9,2	503	12 847	4,8
Conveyor combination system	521	17,5	496	17 940	4
Microcontroller-assisted scale system	506,6	8,05	502	24 988	N/A
Computer-supported scale network system	502,2	13,59	N/A	21 246	N/A

The local storage combination system's punnet mass distribution is shown in Figure 5.5 with the results in Table 5.2. The distribution was skewed towards the lower limit because the dynamic target mass function aimed to make punnet combinations closest to the target mass. With the target mass set the same as the lower limit, 497 g, the achieved average mass was 12,8 g over the target. This shows the target mass functionality to have an observable effect. For this system the upper limit was set higher than for the generic system, this made it easier to use the system in the beginning while the packers were still getting acquainted with it and also increased the throughput. With the external check weigher using the same limits as the packing system, 4,8% of the punnets for the day were rejected at the check weigher because of mass defects. This proves the system's internal check weighing function to be relatively effective, but still subject to human error (Smit, R. *et al*., 2012).

The mass distribution for the conveyor combination system shown in Figure 5.6 is given in Table 5.2. As the system has only limited storage capacity on its conveyor, the throughput can be increased, and run-off at the end of the conveyor can be reduced, by extending the allowable bandwidth of acceptable mass. With the bandwidth at 71 g, the standard deviation is approximately double that of the generic scale and local storage combination systems. Despite this, the distribution is still skewed towards the target mass of 491 g, showing that combinations closer to the target mass enjoy higher priority. 4% of the day's punnets were rejected at the external check weigher due to mass defects (Smit, R. *et al*., 2012).

The microcontroller-assisted scale system does not keep record of every punnet weighed, but saves the average, the standard deviation and the number of punnets for every day. The results are given in Table 5.2. With the target at 502 g, the system had a mere 4,6 g target following error. The standard deviation was the second smallest of the systems, which is due to the dynamic target mass adjustment functionality's adjustment of only the lower mass limit. There is no punnet rejection data available for this system.

The punnet mass distribution for the computer-supported scale network system was also not available; however, the achieved results are given in Table 5.2. The average was just marginally higher than the target of 502 g. The rather large standard deviation shows that the target mass function works effectively by using all of the available bandwidth to achieve the target. The system did not have an external check weigher and therefore no punnet rejection data is available either.

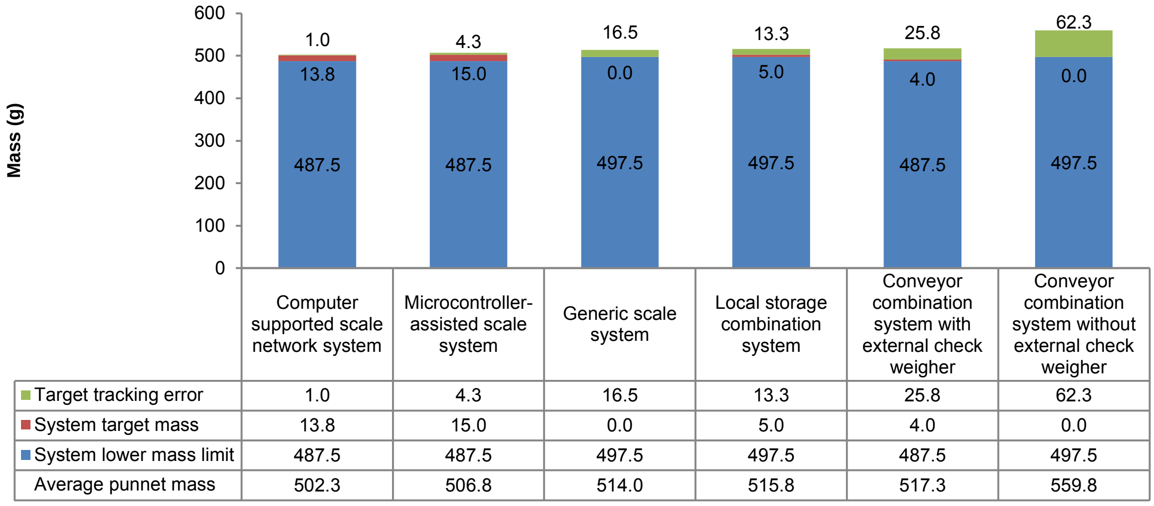
Punnet mass distribution is affected to some extent by target mass tracking, which may lead to savings in giveaway if used correctly. The computer-supported scale system had the best target mass tracking and the conveyor combination system the worst. Standard deviation shows how much mass bandwidth the system has used to produce the punnets. The generic scale system had the narrowest standard deviation, followed by the microcontroller-assisted scale system, the local storage combination system and the computer-supported scale network system, with the conveyor combination system using the most bandwidth.

5.3.2 Giveaway

Producers are paid to deliver punnets of grapes with a net mass of 500 g to the markets (either minimum or average, depending on the mass system used, refer to Section 2.6.2). Any punnets with a content of more than 500 g upon arrival at the market is therefore considered giveaway and is a loss of potential income for the producer. To facilitate comparison between the local and UK data, an average of 2,5% was subtracted from the net mass as recorded by the producer, to compensate for moisture loss during shipping (refer Section 2.2.2).

For the purposes of this comparison, the average punnet mass achieved over the duration of the study was broken up into three parts: The packing system lower mass limit, the target mass set for each system to compensate for moisture loss and the system’s target tracking error, to add up to the average achieved punnet mass. The results are shown in Figure 5.7 as stacked bar graphs making up the average net punnet mass. The lower and upper mass limits, as well as the target mass for each packing system, are given in Table 5.3. The generic scale does not have a target mass functionality and therefore the target mass is equal to the lower limit.

The company considers giveaway of up to 7,5% (37,5 g over the target minimum mass of 500 g) to be an acceptable amount, without limiting the systems too much with regard to bandwidth.



	Computer supported scale network system	Microcontroller-assisted scale system	Generic scale system	Local storage combination system	Conveyor combination system with external check weigher	Conveyor combination system without external check weigher
🟩 Target tracking error	1.0	4.3	16.5	13.3	25.8	62.3
🟥 System target mass	13.8	15.0	0.0	5.0	4.0	0.0
🟦 System lower mass limit	487.5	487.5	497.5	497.5	487.5	497.5
Average punnet mass	502.3	506.8	514.0	515.8	517.3	559.8

Figure 5.7: Composition of net punnet mass per packing system

Table 5.3: Punnet packing system mass settings

System	Computer-supported scale network system	Microcontroller-assisted scale system	Generic scale system	Local storage combination system	Conveyor combination system with external check weigher	Conveyor combination system without external check weigher
Lower limit	487,5 g	487,5 g	497,5 g	497,5 g	487,5 g	497,5 g
Target mass	501,3 g	502,5 g	497,5 g	502,5 g	491,5 g	497,5 g
Upper limit	527,5 g	517,5 g	527,5 g	557,5 g	557,5 g	557,5 g
Mass system used	Average	Average	Minimum	Minimum	Average	Minimum

Figure 5.7 shows that the computer-supported scale network system was able to track its target mass very accurately. The packing system was used to produce punnets for the average mass system and therefore the minimum was set to 487,5 g. Initially the target mass was set to 497,5 g, but it was later increased to 502,5 g to compensate for increased moisture loss in the open top punnets used. The target given in Figure 5.7 and Table 5.3 is therefore the average calculated over the duration of the study. With a 0,5% giveaway on the 500 g target minimum mass and a 0,2% target tracking error, this system showed the biggest savings as regards giveaway.

The microcontroller-assisted scale system was operated with a narrower bandwidth than the computer-supported scale network system and used a target of 502,5 g for the duration of the study, see Table 5.3. This packing system accomplished a 1,4% giveaway on the 500 g target minimum mass with a target tracking error of just 0,8%. With the narrow bandwidth and small target tracking error, this system is well suited for use with the average mass system as well.

The generic scale system does not have a target mass or any packing-assist functionality. The target was set as the lower limit for calculation purposes. With an average punnet net mass of 514 g for the duration of the study, as well as a narrow 30 g bandwidth, the system had a 2,8% giveaway on the 500 g target minimum mass from Figure 5.7.

Normally the local storage combination system's bandwidth is set to 50 g, with the target the same as the lower limit in order to minimise giveaway. To increase throughput, the bandwidth was set to 60 g with the target 5 g higher than the lower limit, refer to Table 5.3. As a result of the wide bandwidth, this system had a giveaway of 3,2% on the 500 g target minimum mass, refer to Figure 5.7. Because the system was producing punnets for the minimum system, the target was set close to the lower limit, it therefore had a 2,6% target tracking error. The target tracking error and giveaway could be reduced by narrowing the bandwidth to 50 g as is the standard setting.

Lastly, the two conveyor combination systems are viewed. One system had an external check weigher added and the other did not. These two systems will be used to discuss the effect of external check weighing on the conveyor combination system. The system without external check weighing will be used as a benchmark for comparing the two. As discussed in Section 5.3.1, the bandwidth for this system is increased to increase the throughput and reduce the runoff at the end of the conveyor. For the benchmark system the target mass was set the same as the lower mass limit, because it was producing punnets for the minimum system, see Table 5.3. From Figure 5.7 the system had a giveaway of 12% on the 500 g target minimum mass and a 12,5% target tracking error. This level of giveaway is much more than the acceptable amount.

The external check weigher was incorporated in the second conveyor combination system in the following manner: The finished punnets from the system all pass over the check weigher. The system was set up as in Table 5.3 for the average system with lower mass limit 487,5 g and upper mass limit 557,5 g for maximum throughput and the target mass at 491,5 g for the lowest possible punnet mass. The check weigher was set up with lower limit 494 g and upper limit 547,5 g. This setup allowed the system to have a higher throughput, while eliminating the under mass and over mass punnets using the check weigher. With this setup the system achieved an average giveaway on the 500 g target minimum mass of 3,5% with a 5,2% target tracking error. The check weigher parameters were set up so that the check weigher operator would always have punnets to fill correctly and thus add to the productivity. These results compare well with the other systems.

Giveaway is another way of determining accuracy, in conjunction with punnet mass distribution. Giveaway is affected by the setup of the packing systems and the mass system used (average or minimum). The computer-supported and the microcontroller-assisted scale systems had the least giveaway, with the microcontroller-assisted scale system also having the narrowest bandwidth. The third best system, in terms of setup, was the generic scale system. It had the same bandwidth as the microcontroller-assisted system, but with more giveaway (although still less than half of the allowed amount of giveaway). With the conveyor combination system, check weighing made a considerable difference. Additional check weighing more than halved the giveaway of the system, while also increasing the throughput.

5.4 Effect of check weighing: Validation by means of punnet mass feedback from the UK

The aim of this section is to determine if under mass punnets can be eliminated effectively using automated check weighing (step 1.3.3.4 of the research goal). It will also complete the second part of step 1.3.2.4 by determining the real occurrence of under mass punnets.

Upon arrival at the company's UK operation, the punnets are flow wrapped according to order size for delivery to different customers. During this process the punnets are check weighed once more to ensure mass quality and the results are sent back to the production units as a means of pro-active customer feedback (Codron, J.M. *et al*., 2005; Republic of South Africa National Agricultural Marketing Council, 2007; Finch, Byron J., 2008). Two sets of data were obtained from the UK, one for the 2010/2011 packing season and one for the 2011/2012 packing season. The UK data was grouped according to pack house, and as a result the local storage combination, generic and microcontroller-assisted scale systems were all grouped together. The conveyor combination and computer-supported scale network systems were separate. The results are shown in Figure 5.8.

During the 2010/2011 packing season the local storage combination, generic scale and conveyor combination systems did not have any external check weighers as opposed to the 2011/2012 packing season where they all did. For the 2011/2012 packing season both the microcontroller-assisted scale system and the computer-supported scale network system replaced generic scale systems in their respective pack houses. The microcontroller-assisted scale system had external check weighing and the computer-supported scale network system had only internal check weighing functionality, as stated in Table 5.1.

Since 2010 the emphasis on giveaway, as regards both minimum and maximum punnet mass, has increased and resulted in a lower, narrower allowable mass bandwidth, as shown in Table 5.4. The upper mass limits for the 2011/2012 season were not enforced, but rather set as goals. In this section the UK data for the two packing seasons will be compared, to validate the effect of adding check weighers to the respective systems.

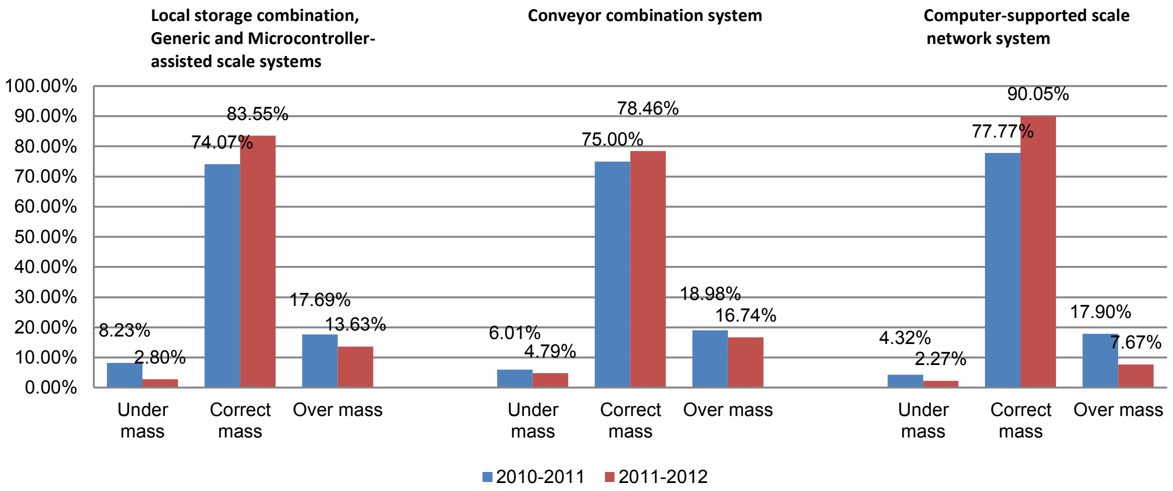


Figure 5.8: UK punnet mass feedback

Source: Smit, R. *et al.*, 2012

Table 5.4: UK check weighing punnet mass limits

Packing system	2010/2011		2011/2012	
	UK lower mass limit (g)	UK upper mass limit (g)	UK lower mass limit (g)	UK upper mass limit (g)
Local storage combination system, generic scale system and microcontroller-assisted scale system	500	550	490	520
Conveyor combination system	500	550	490	520
Computer-supported scale network system	500	550	490	530

A comparison between the two sets of seasonal punnet mass data from the UK for the first pack house incorporating the local storage combination, generic scale and microcontroller-assisted scale systems is shown in Figure 5.8.

The 2011/2012 packing season showed distinct improvements on every level following the addition of external check weighers. The large number of over mass punnets during the 2011/2012 season could be attributed to upper mass limits for the local storage combination and generic scale systems as given in Table 5.3 being higher than the UK goal. This could have been a communication error, or it could have been an attempt by the pack house manager to increase throughput. Despite the significant decrease, under mass punnets still accounted for 2,8% of the total checked in the UK.

The feedback results for the conveyor combination system also show an increase in punnets with the correct mass, see Figure 5.8. However, the improvement seen for this system was smaller than that achieved at the first pack house. This could be because the pack house mass limits did not correspond with the UK specifications. The small decrease in under mass punnets could be because open top punnets were used for packing the grapes, which resulted in a moisture loss greater than the 2,5% compensated for. The system's upper limit was 27,5 g higher than the UK limit and the average punnet mass was a mere 2,7 g lower than the UK upper limit; this explains the great number of over mass punnets recorded in the UK.

The comparison for the computer-supported scale network system is presented by the rightmost group of columns in Figure 5.8. It should be noted that the 2010/2011 results were for a generic scale system, which was replaced by a computer-supported scale network system for the 2011/2012 packing season. The new system showed an increase of 12,2% in correct mass punnets over the generic scale system. As with the first comparison, under mass punnets were reduced to a very small number, but not eliminated.

A possible reason could be the lower limit of 487,5 g at the pack house, which was just lower than the 490 g UK limit, while the over mass punnets could be attributed to operators ignoring the internal check weighing system warning, when they realised that there was an over mass error.

The addition of external check weighers during the 2011/2012 packing season saw an average in under mass punnets from 6,19% to 3,29%. The remaining under mass punnets could in some cases be attributed to the packing system mass limits not corresponding to the UK limits, but most often it could be attributed to human and machine errors, refer to Section 2.5.3. Although it runs fully automated, the check weigher still needs to be set up by a human. In a typical case of human error the air pressure to the faulty package separation unit was never turned on during setup and, although the check weigher detected the faulty packages, it could not remove them from the production line.

5.5 Conclusions

The productivity study comprised five of the six punnet packing systems described in Chapter 3. This study was conducted in order to complete three and update one of the steps towards accomplishing the research goal. Step 1.3.2.2 (Determine the productivity of current packing practices); step 1.3.2.3 (Determine the accuracy of current packing practices); step 1.3.2.4 (Determine the statistical parameters of under mass punnet occurrence and the financial implications thereof) were completed; and step 1.3.3.4 (Determine if under mass punnets can be eliminated effectively using automated check weighing) was further addressed.

In order to compare the different packing systems on an equal basis, the actual throughput was divided by the total man-hours to calculate the productivity in punnets produced per man-hour. The generic scale system had the smallest throughput and is also quite labour intensive, thus rendering it the least productive. Although the conveyor combination system had the second largest actual throughput, it is very labour intensive, making it the second least productive. The productivity results of the other three systems are close to each other, because all three are based on the principles of lean production, requiring the minimum amount of labour. All of these systems exceeded the company target for productivity.

The accuracy of a manufacturing process is determined by its variability and controllability. The variability relates to the bandwidth and standard deviation for each process and the controllability is the ability of the process to follow the target mass. The optimal punnet packing system would be able to produce punnets with excellent target mass tracking, using the narrowest bandwidth and produce the least number of defects (preferably none). This would allow total control over the process.

The systems differed greatly in standard deviation from 7,2g for a 30 g bandwidth (generic scale system) to 17,5 g for a 70 g bandwidth (conveyor combination system). The goal for bandwidth was 30 g, but this was increased for some systems to raise the throughput. In terms of target mass tracking, the computer-supported scale system performed best, with a mere 0,2% error, followed by the microcontroller-assisted scale system with 0,8% tracking error, the local storage combination system with a 2,6% error and the conveyor combination system with a 5,2% tracking error.

The packing systems used for the minimum mass system had more giveaway than those used for the average mass system; they also had worse target mass tracking, because the target mass values were set equal to the minimum mass limit. The addition of check weighing to the conveyor combination system more than halved the giveaway and variance, making the system much more accurate. Throughput also improved; all without negatively affecting the productivity of the system.

To determine how effectively check weighing can reduce the occurrence of under mass punnets, mass results from the producer's UK operation were compared from before check weighing was added to the packing systems and after. This showed that although check weighing resulted in a 2,9% average decrease in under mass punnets, under mass punnets still accounted for an average of 3,29% of the exported punnets. Check weighing also decreased the number of over mass punnets by 5,51% notwithstanding the use of different upper mass limits.

Possible reasons for the still significant number of under mass punnets are both human and machine related. Human error results because people do not go through the correct setup procedure when starting up the check weigher in the morning, resulting in problems such as there being no air pressure for the pneumatic faulty-package separator unit. A typical machine error was the failure of proximity sensors to detect punnets, as well as the feed rates of conveyor belts being too high.

The check weighers in this study were used with the default factory setup. In the next chapter experiments are performed on the check weigher to determine whether this really is the best setup. The results are then evaluated against the user requirements collected throughout the thesis.

6. Results: Check weigher experiments

Only minimal technical data was available regarding the accuracy of mass measurement for table grape punnets for the check weighers used at the pack houses during the 2011/2012 season. The supplier claimed that the check weigher would be accurate to within ±2 grams of the real mass. An experimental setup was designed to simulate a real world implementation for the check weigher, as well as a laboratory setup for comparable results in ideal conditions.

6.1 Introduction

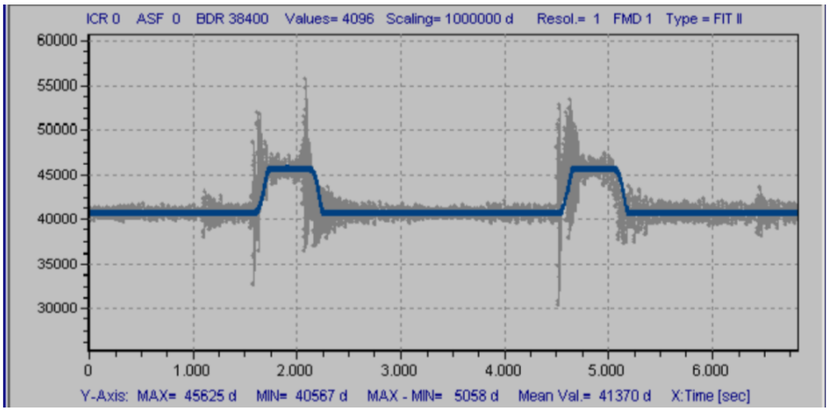
The main goal of the experiments was to complete step 1.3.3.3 of the research goal to determine whether the check weigher satisfies all the requirements set for automated check weighing during the course of the thesis. The main goal was thus to check the variance in mass measurement. Subsequent goals were to test for punnet rejection at the upper and lower mass limits; to investigate the effect of conveyor height level differences on measurement accuracy; to investigate the effect of timing between the weighing of successive punnets.

6.1.1 Check weigher functioning

The section of the check weigher under investigation is the load cell and conveyor belt assembly. It could be regarded as an under-damped oscillating spring-mass system with the load cell as the spring element and the conveyor, and objects to be weighed, acting as the mass (Hottinger Baldwin Messtechnik GmbH, 2011). Objects (punnets) move across the weigher at a constant speed.

During operation the electric motors that drive the conveyor belts excite vibration at resonance frequencies which could lead to measurement errors. An object causes vibration as it arrives on the load cell from the speed-up conveyor belt and again as it leaves the load cell. The amplitude of the vibration depends on the mass of the object and the dynamic stability of its content.

The load cell has internal digital filter functions with different cut-off frequencies that can be set up to filter out the resonance frequencies from the motors and the object-and-load cell conveyor belt unit. The process is described in Figure 6.1, with the original unfiltered signal shown in grey and the filtered signal in blue. The figure shows the output of a HBM FIT load cell, which is very similar to the load cell used in the check weigher. The blue signal represents the output with the best filter selected.



ICR 0 ASF 0 BDR 38400 Values= 4096 Scaling= 1000000 d Resol.= 1 FMD 1 Type = FIT II

Y-Axis: MAX= 45625 d MIN= 40567 d MAX - MIN= 5058 d Mean Val.= 41370 d X:Time [sec]

Figure 6.1: Filtered output signal of a HBM load cell

Source: Hottinger Baldwin Messtechnik GmbH, 2011

6.1.2 Requirements for automated check weighing

During the course of the thesis some requirements for automated check weighing (step 1.3.3.2 of the research goal) have been stated. This section will list these requirements and the rest of the chapter will verify whether these are satisfied by the check weigher.

To conform to the average mass system, the check weigher must be able to weigh each punnet accurately to within one fifth of the tolerable negative error (TNE). For 500 g punnets this means an accuracy of ±3g. Mass records of all qualifying punnets are required to be kept for at least one year. The maximum capacity per hour must be calculated to determine the number of check weighers needed per system.

The check weigher does allow for record keeping to be recorded on a remote computer, refer to Section 2.6.2. The variance and maximum hourly capacity must therefore be determined. The ±2 g variance stated by the supplier will be used as the target for accuracy.

6.2 Experimental setup

At first the check weigher experiments were conducted only in a factory setup, in order to simulate a real world implementation, it was then deemed necessary to repeat some of the experiments in a laboratory setting as well, for the purpose of comparison.

6.2.1 Factory

In a natural setting the check weigher would be part of a packing line inside a pack house. Punnets would be fed by a conveyor from the packing stations; the check weigher would speed up the punnets before they passed over the load cell and entered the faulty package separator unit; qualifying punnets would then be taken away to the packaging stations by another conveyor. For the experimental setup to resemble the natural setting, the experiment was conducted at an industry partner’s production factory. A conveyor was set up to feed the punnets from the check weigher’s output back to the input. The setup is shown in Figure 6.2. The input, speed-up, load cell, faulty package separator unit and output conveyors were all set to the same height level.

The check weigher speed-up and load cell sections were not connected to the rest of the system, as in the natural setting, to reduce vibration from the adjacent conveyors.

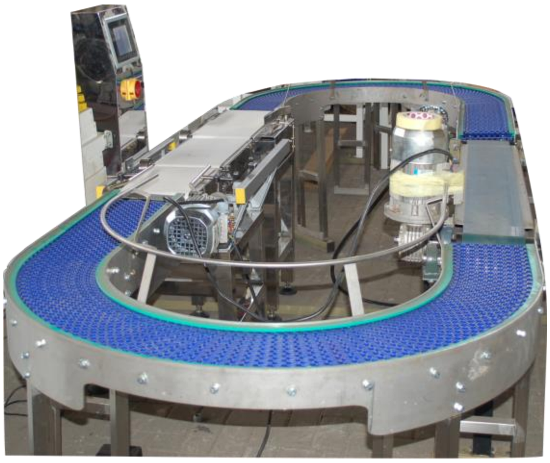


Figure 6.2: Check weigher in experimental factory setup

6.2.2 Laboratory

For the laboratory experiments the check weigher and faulty package separator units were set up in a closed room with a carpeted floor. Structures were erected at the input and output ends of the check weigher system at the same level as the check weigher conveyor belts, as shown in Figure 6.3. Punnets were gently pushed from the first structure onto the speed-up conveyor and left to run off the output end of the check weigher onto the other structure.

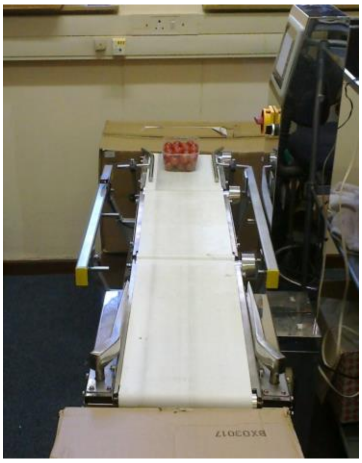


Figure 6.3: Check weigher experimental laboratory setup

6.2.3 General

At the time the experiments were conducted, table grapes were out of season and therefore loose cocktail tomatoes in table grape punnet containers were used. Cocktail tomatoes are similar to table grape berries in shape, mass and firmness. They were therefore assumed to behave dynamically similar as well, with no need to adapt any check weigher parameters.

Certain check weigher parameters can be modified. These parameters are described in detail in the check weigher operating manual in Addendum D. The most important parameters and their initial values are shown in Table 6.1 (The initial setup was not necessarily intended for table grape punnets, although it was used for this purpose during the 2011/2012 packing season). The 'T1 time', 'T2 time', 'T3 time' and 'P1 time' parameters relate to the conveyor belt speed and the dimensions of the check weigher as depicted in Figure 6.4.

Table 6.1: Check weigher parameters

Parameter	Description	Default value
CollTimes	The number of sampled mass measurements to be collected and averaged for final mass calculation	5
ZeroRang	Maximum allowed correction for automatic zero tracking function	10
T1 time	Time between product detection and first measurement	100 x 5 ms
T2 time	Time between unqualified product detection and activation of pneumatic removal arm	1 x 5 ms
T3 time	Time from product detection until product leaves the check weigher	150 x 5 ms
P1 time	Duration of pneumatic removal arm activation	40 x 10 ms
SampRate	Sampling rate for load cell mass measurements	3
FilterCoe	The filter coefficient parameter is used to select one of nine internal digital filters with different cut-off frequencies	5
DynaCoef	Dynamic coefficient, a ratio used to correct the difference between the displayed and the real mass	1.000
ULWeight	Upper mass limit	0.575 Kg
TaWeight	Product target mass	0.550 Kg
LLWeight	Lower mass limit	0.525 Kg

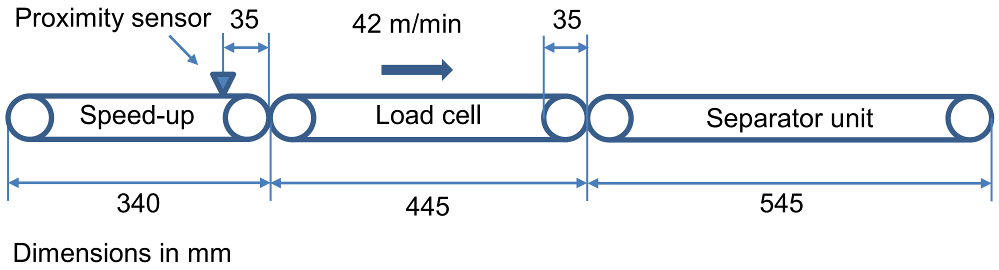


Figure 6.4 Check weigher layout

At the beginning of each day, and whenever parameters were changed, the check weigher was recalibrated according to the operating manual (refer to Addendum D) using a certified 10 kg calibration mass supplied with the check weigher. A separate scale was used to verify the mass of each test punnet. This scale was calibrated beforehand and a certified 500 g calibration mass was used to check the calibration at the start of each day.

A laptop computer was connected to the check weigher to record the mass values. This was similar to the real world pack house setup where a computer in a separate room would be connected to the check weigher to log the punnet weights. This basic setup was used for all the check weigher experiments to follow.

6.3 Variance test results and discussion

The purpose of the variance test was to determine the optimal check weigher configuration in order to minimise the variance of mass measurements. The test specific setup, experimental results and a discussion follow for both the factory and the laboratory tests.

6.3.1 Factory

The results for all the factory variance tests are given in Table 6.2. For each test the gross mass of the test punnet was noted, as well as the resulting mean, mode, standard deviation and range of the check weigher mass measurements. The probabilities of the weights falling within the ±2 g variance about the mean were calculated using the z-table.

Table 6.2: Check weigher variance test results - Factory

Test no.	Gross mass (g)	Mean (g)	Mode (g)	Standard deviation (g)	Range (g)	Probability ±2 g (%)
1	538	530,5	530	1,6	7	79,8
2.1	538	538,4	539	2,9	14	51,4
2.2	538	538,6	539	1,3	7	87,5
2.3	538	538,4	538	1.3	8	87.5
2.4	576	575,5	577	1,7	8	75,4
4.1	539	539,6	540	0.7	3	99.8
4.2	576	575,9	576	0,7	3	99,8
5	538	537,6	538	0,5	2	99,9

Test 1: Initial setup test

For the first factory test the initial parameter settings from Table 6.1 were used. A single punnet of cocktail tomatoes was weighed 50 times. The resultant distribution is shown in Figure 6.5; it was approximately normal with the parameters as given in Table 6.2. The 7,5 g deviation from the mean of the real mass could be rectified using the dynamic coefficient ratio, ‘DynaCoef’.

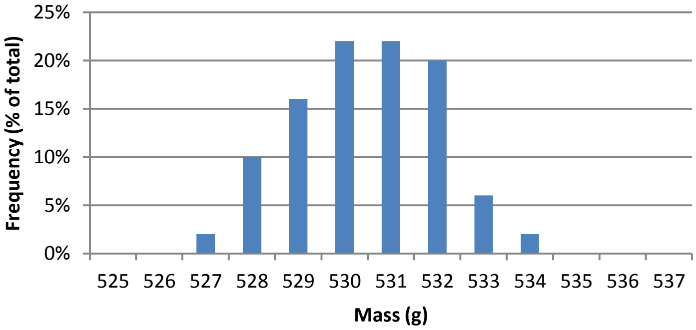


Figure 6.5: Test 1 Initial setup mass distribution

This result was not satisfactory and therefore a better parameter setup had to be found.

Test 2: Digital filter selection test

With the initial setup, the load cell had a sample rate of 120 Hz. Starting at time T1, the mass was sampled 22 times while the whole punnet was on the load cell. With ‘CollTimes’ = 5, the first five sampled mass values were collected and averaged to get the final displayed mass.

Test 2.1: Initial digital filter with more collected samples

To test whether the selected digital filter had a cut-off frequency low enough to filter out the resonance frequencies of the motors as shown in Figure 6.1, more of the sampled mass values could be collected and averaged. If the cut-off frequency was low enough, the accuracy of test 2.1 would increase, or at least not be worse than that of test 1.

Test 1 was repeated with the ‘CollTimes’ parameter increased to 10, the check weigher was also recalibrated before the test. The resultant parameters are given in Table 6.2. The mass distribution is shown in Figure 6.6.

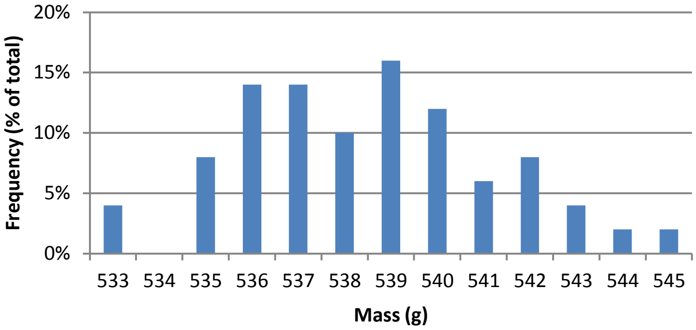


Figure 6.6: Test 2.1 Digital filter selection mass distribution

The observed decrease in accuracy indicated that the selected digital filter’s cut-off frequency was too high, and that therefore the vibration from the object-and-load cell conveyor belt unit was not damped sufficiently. It was also observed that recalibration significantly decreased the deviation of the mean displayed mass from the real mass. Thus, the check weigher needed to be calibrated carefully, and the displayed mass verified afterwards, before operating in automated mode.

Test 2.2: Digital filter with lower cut-off frequency

To reduce vibration in the load cell signal, the load cell filter coefficient parameter, ‘FilterCoe’, was changed to 7. This would select a digital filter with a lower cut-off frequency to increase damping of the object-and-load cell conveyor belt unit vibration and, subsequently, the accuracy of the sampled mass measurements. A consequence of the lower cut-off frequency would be a longer settling time for the filter (Hottinger Baldwin Messtechnik GmbH, 2010); therefore T1 was increased to 105.

A punnet was weighed 100 times with the results as given by Table 6.2 and Figure 6.7. A 7,7% increase in the number of recorded weights within the allowable ±2 g variation about the mean was observed with respect to the initial setup in test 1.

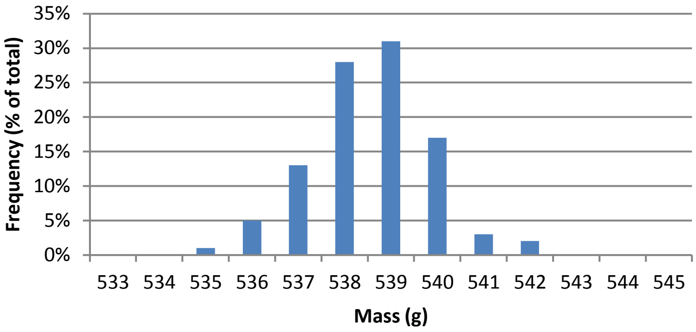


Figure 6.7: Test 2.2 Digital filter selection mass distribution

Test 2.3: More collected samples

In order to verify that the vibrations were sufficiently filtered out with the new filter coefficient, test 2.2 was repeated, but more sampled mass measurements were collected and averaged. With T1 = 105, the punnet mass would be sampled 19 times while the whole punnet was on the load cell. Hence, the ‘CollTimes’ parameter was increased to 18.

The results are shown in Figure 6.8 and were very similar to those of test 2.2, as can be seen in Table 6.2. The increase in collection times resulted in a narrower distribution, but also an increase in the range, due to some out-of-control weights. Gitlow defines these out-of-control weights (weights 35 and 46 in Figure 6.9) as freak weights caused by external disturbances, because they occur at or beyond three standard deviations from the mean (Gitlow, H.S. *et al*., 2005). This could be an indication that the vibrations from the object-and-load cell conveyor belt unit were still not sufficiently damped at the time of measurement.

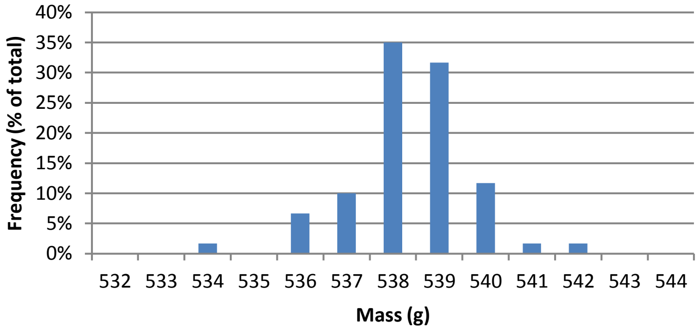


Figure 6.8: Test 2.3 Digital filter selection mass distribution

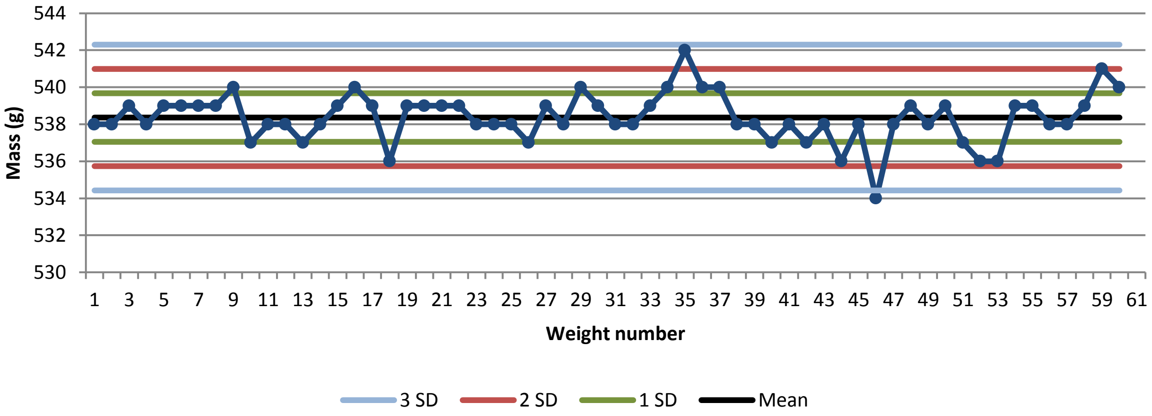


Figure 6.9: Test 2.3 Digital filter selection weights in sequence

Test 2.4: Greater punnet mass

For an oscillating spring mass system, a greater mass would lower the resonance frequency. To ensure that vibrations were sufficiently damped at the upper mass limit of the check weigher, a heavier punnet was weighed 100 times. Figure 6.10 and Table 6.2 shows the resulting distribution. A 12,1% decrease in weights within the allowable range was observed, as a result of the heavier punnet. This clearly indicated instability in the load cell signal.

During this test no freak weights were recorded. The freak weights in Figure 6.9 from test 2.3 were therefore not associated with the increase in number of mass values collected.

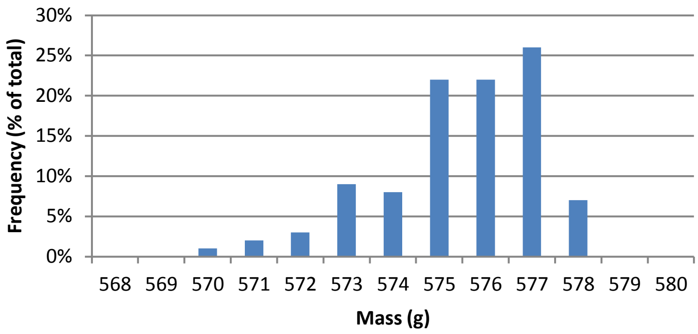


Figure 6.10: Test 2.4 Digital filter selection mass distribution

Test 3: Reduced punnet cycle time

With the normal factory experimental setup the punnet passed over the check weigher load cell once every 20 seconds. In the real world pack house implementation punnets would pass over the load cell much more often. In this test the same parameter setup as in the previous test was used, but the 538 g punnet was picked up immediately after passing over the load cell conveyor and moved back to the start of the speed-up conveyor. One cycle took about 3,5 seconds.

The distribution of mass measurements is shown in Figure 6.11. The results showed two clear distributions, 7 g apart. From Figure 6.12 it can be seen that weights 39 through 73 were on average 7 g lower than weights 1 through 38 and 5 g lower than 74 through 100. Gitlow defines this phenomenon as a grouping pattern caused by the introduction of a new system of disturbances into the process (Gitlow, H.S. *et al*., 2005). Both distributions had a similar standard deviation to that of test 2.3, therefore the phenomenon seems to have been caused by a zero or tare function.

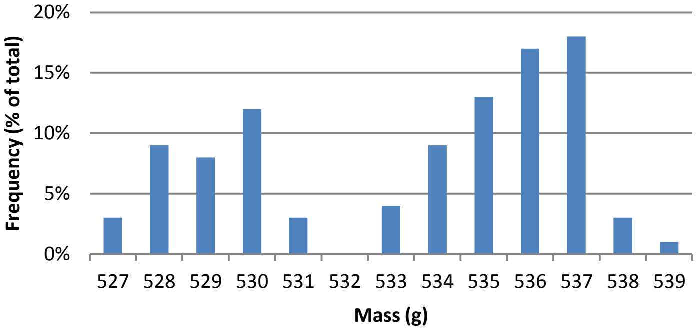


Figure 6.11: Test 3 Reduced punnet cycle time mass distribution

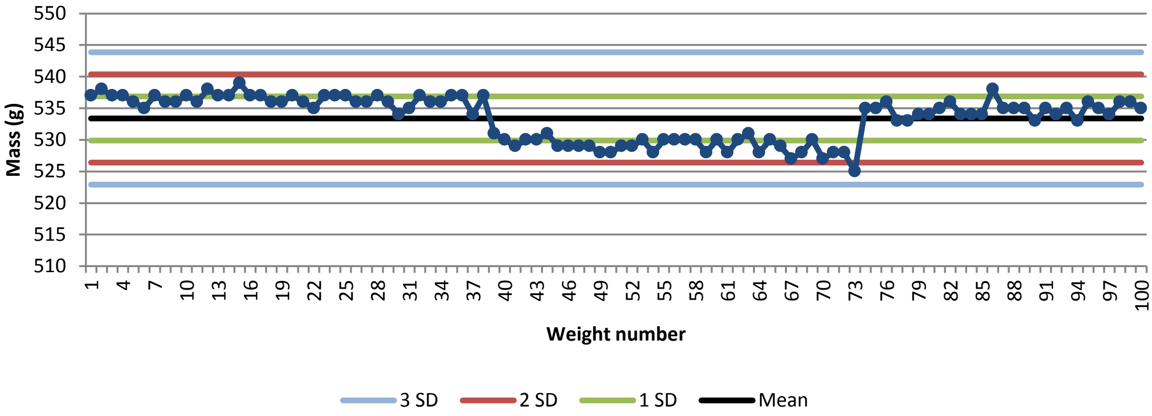


Figure 6.12: Test 3 Reduced punnet cycle time mass measurements in sequence

The check weigher has a built-in zero tracking function. Once a minute this function measures the zero point of the load cell and compares it with the previously measured zero points. The maximum allowed correction is determined by the ‘ZeroRang’ parameter. The zero point is measured while the load cell is unladen, thus from time T3 after punnet *n* passed the proximity sensor until the time punnet *n+1* passes the proximity sensor. With T3 = 150 the punnet was still partly on the load cell at the time the zero tracking function started to measure the zero point. During the previous tests the load cell and conveyor belt section had remained unladen for longer periods of time between punnets *n* and *n+1*, allowing the zero tracking function to correctly measure the zero point and adjust it.

However, during this test the load cell was unladen for shorter periods of time and therefore the zero tracking function could probably not measure the zero point correctly, and applied a 7 g downwards correction for 2 minutes before managing to measure the zero point more accurately and adjusting it 5 g upwards.

Test 4: Manufacturer suggested settings

When presented with the results of test 3, the manufacturer suggested setting T1 = 130 and T3 to any time after the punnet had left the load cell conveyor belt (Guangdong HighDream, 2011). The longer T1 time would allow the system to stabilise before any measurements were taken. From Figure 6.4, T3 = 210 was chosen, allowing the front of the punnet to be 255 mm past the load cell conveyor before the zero point was measured. The first mass measurement would occur 455 mm after punnet detection, allowing the punnet mass to be sampled 4 times before it left the load cell conveyor belt. Therefore the number of collected sample values, ‘CollTimes’, was also changed to 4.

Test 4.1: Manufacturer suggested settings with normal mass punnet

A test punnet was weighed 100 times using the same method as in test 3. The distribution is shown in Figure 6.13 with resulting parameter given in Table 6.2.

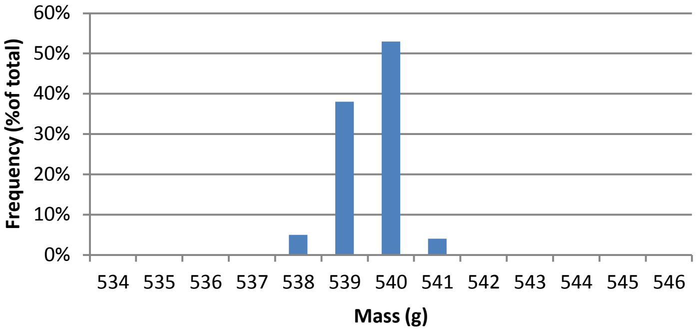


Figure 6.13: Test 4.1 manufacturer suggested settings mass distribution

The increased ‘T1 time’ allowed the vibrations to be damped sufficiently before measuring the mass and thus improved accuracy. The increased ‘T3 time’ ensured that the zero tracking function would only measure the zero point when the load cell conveyor was unladen.

Test 4.2: Manufacturer suggested settings with greater punnet mass

In order to ensure that a greater object mass would not affect the accuracy of mass measurements as shown for test 2.4 in Figure 6.10, test 4.1 was repeated with a heavier punnet. The result is shown in Figure 6.14 with the parameter given in Table 6.2. This test showed similar results to those of test 4.1 and therefore this was chosen as the optimal parameter setup for use with the check weigher.

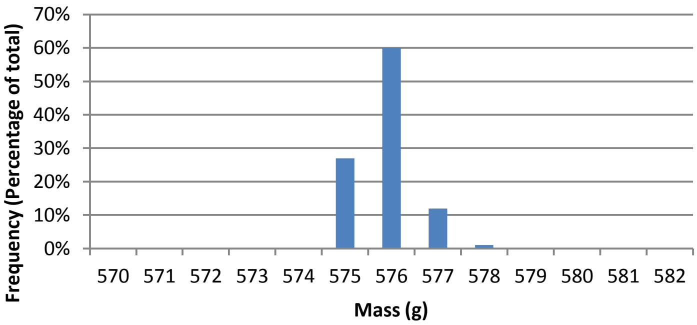


Figure 6.14: Test 4.2 Manufacturer suggested settings with heavier punnet mass: distribution

Table 6.3: Optimal check weigher parameter setup

Parameter	Default value	Optimal value
CollTimes	5	4
T1 time	100 x 5 ms	130 x 5 ms
T3 time	150 x 5 ms	210 x 5 ms
FilterCoe	5	4

Test 5: Accuracy with stationary load cell conveyor belt

For this test the conveyor belt was kept stationary in order to eliminate any vibrations resulting from the motors and belts. The punnet was put on the load cell, the proximity sensor was triggered by hand and the punnet was then removed for about one second before repeating the cycle. The object of this test was to determine the effect on accuracy of the movement of the conveyor and punnet belt.

The test was conducted using a 538 g punnet and the results are given in Table 6.2. The distribution is shown in Figure 6.15. This was only slightly more accurate than with the dynamic setup of test 4.1. It was therefore concluded that the effect of the moving conveyor belt on the accuracy of measurements was negligible with the current setup.

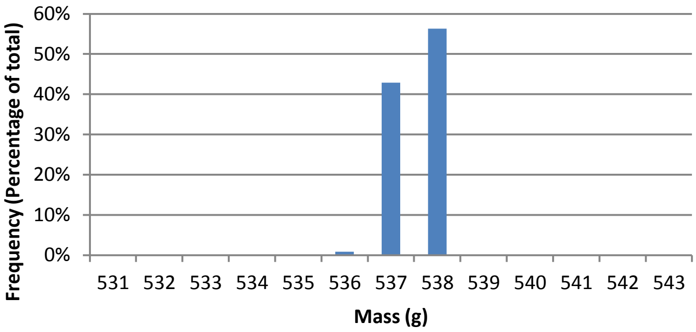


Figure 6.15: Test 5 Stationary conveyor belt mass distribution

6.3.2 Laboratory

The results for all the laboratory variance tests are given in Table 6.4. For each test the gross mass of the test punnet was noted, as well as the resulting mean, mode, standard deviation and range of the check weigher mass measurements. The probabilities of the weights falling within the ±2 g variance about the mean were calculated using the z-table.

Table 6.4: Check weigher variance test results - Laboratory

Test no.	Gross mass (g)	Mean (g)	Mode (g)	Standard deviation (g)	Range (g)	Probability ±2 g (%)
6	531	536,1	536	1,5	7	81,8
7	531	539	539	1,1	4	92,2
8	531	528,4	528	0,6	2	99,9
9.1	531	531,4	531	0,5	2	99,9
9.2	574	574	574	0,2	1	100

Test 6: Initial setup test

The first laboratory test was a replica of test 1, using a punnet of cocktail tomatoes, but with a cycle time of 3,5 seconds as opposed to 20 seconds for the factory test.

The results are shown in Figure 6.16 and Table 6.4. There was a 2% increase over test 1 conducted in the factory.

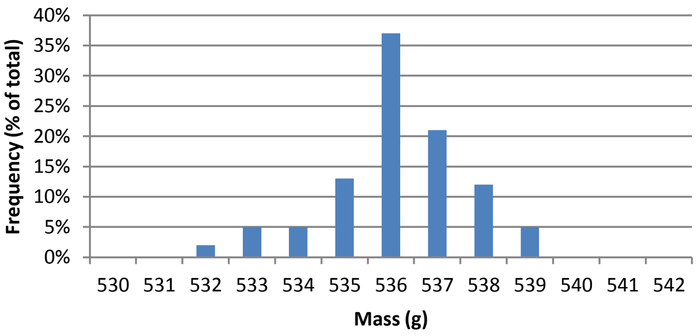


Figure 6.16: Test 6 Laboratory initial setup mass distribution

A view of the measured mass values over time in Figure 6.17 revealed the process to be out of control, according to (Gitlow, H.S. *et al*., 2005). The instability was largely caused by weights 12 through 21 and again by weights 78 through 88. As with factory test 3, these were grouping errors, usually caused by the introduction of a new system of disturbances to the process. In the third factory test these disturbances were attributed to the zero tracking function.

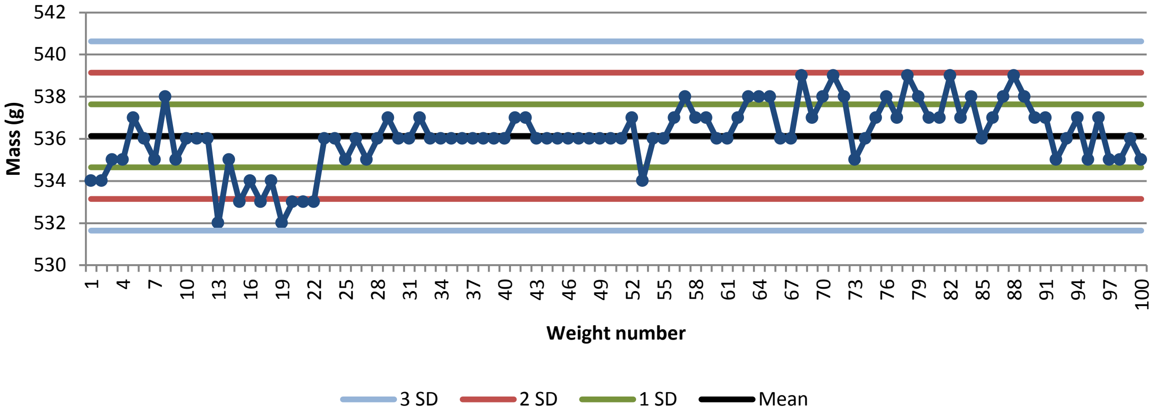


Figure 6.17: Test 6 Laboratory initial setup: mass measurements in sequence

Test 7: Digital filter selection test

Test 2.2, with the lower cut-off frequency selected, was replicated using a punnet with a 3,5 s cycle time. The results are shown in Figure 6.18 and Table 6.4. There was a definite increase in accuracy over the factory experiment, despite the clear grouping errors caused by the zero tracking function, as can be seen in Figure 6.19, for weights 87 to 99.

The increased accuracy in the laboratory tests could possibly be attributed to the absence of low frequency vibration through the factory floor caused by machinery and moving fork lifts (Haga, K. *et al*., 2000).

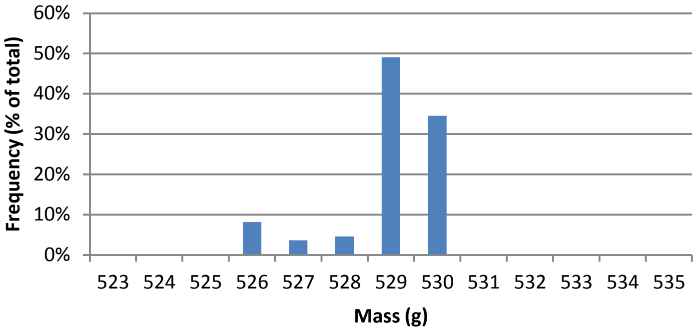


Figure 6.18: Test 7 Laboratory digital filter selection: mass distribution

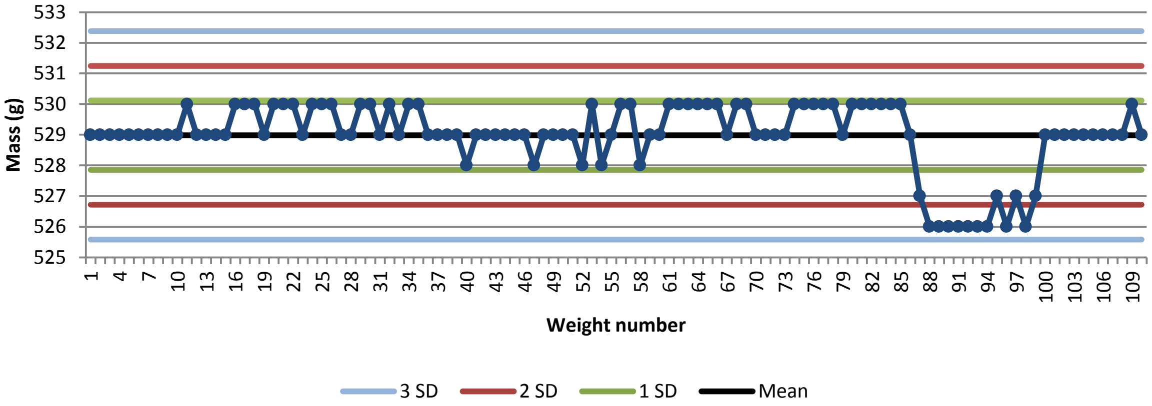


Figure 6.19: Test 7 Laboratory digital filter selection: mass measurements in sequence

Test 8: Zero tracking function test

In order to verify that the zero tracking function was responsible for the grouping errors, the ‘ZeroRang’ parameter was reduced from 10 to 1 and the previous test was repeated. This produced a similar distribution to that of test 7, but without the grouping errors, as can be seen in Figure 6.20. The resulting parameter are given in Table 6.4.

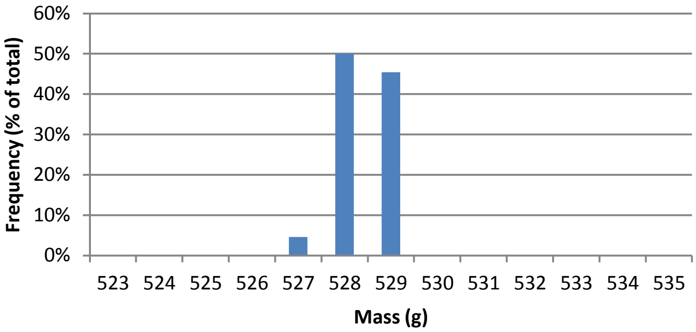


Figure 6.20: Test 7 Laboratory zero tracking mass distribution

This result looked very promising, but it was unclear what the long term effect of the reduced zero tracking parameter would be. The manufacturing company recommended that the ‘ZeroRang’ parameter should be between 10 and 15 and stressed that a value of 1 would allow the load cell zero point to drift after a while.

Test 9: Manufacturer suggested settings

The manufacturing company suggested T1 = 130, T3 = 210 and ‘CollTimes’ = 4 (as calculated for test 4). ‘ZeroRang’ was also changed to 10. The increased ‘T1 time’ would allow a much longer settling time for the filter and therefore the sampled values would be more stable. The increased ‘T3 time’ ensured that the zero tracking function would measure the zero point only when the load cell conveyor was unladen, which would eliminate or reduce the grouping error.

Test 9.1: Manufacturer suggested settings with normal mass punnet

A punnet of cocktail tomatoes was weighed 211 times with the resulting parameter as given in Table 6.4. The mass distribution is shown in Figure 6.21, and the mass measurements in sequence in Figure 6.22. These results showed improvements in every aspect over the equivalent factory test and over the previous laboratory test.

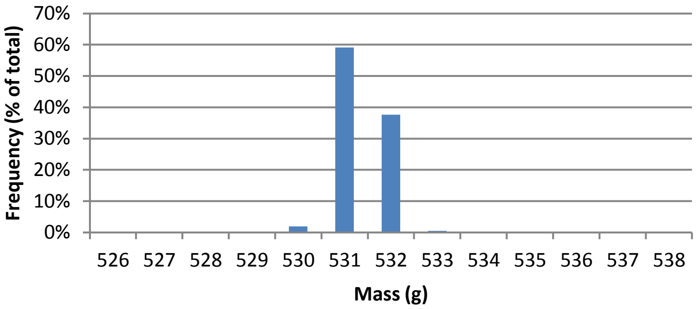


Figure 6.21: Test 9.1 Manufacturer suggested settings: mass distribution

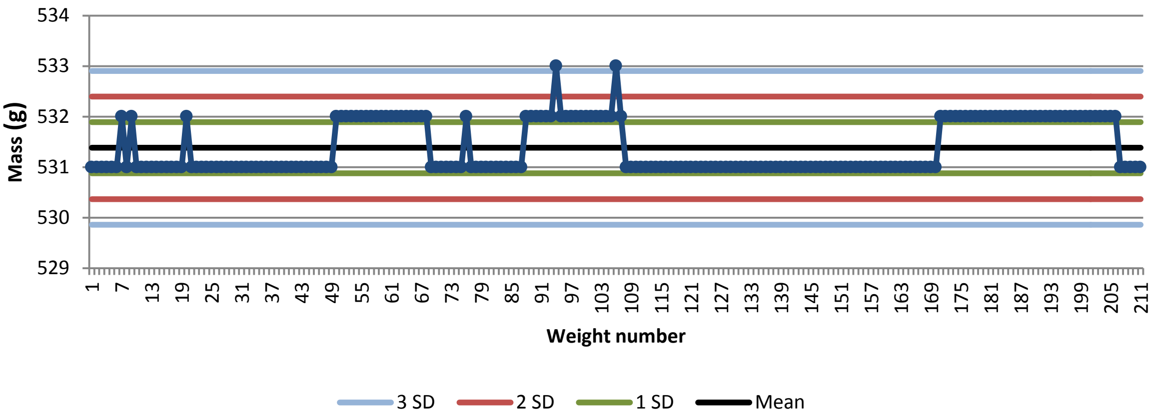


Figure 6.22: Test 9.1 Manufacturer suggested settings: mass measurements in sequence

In Figure 6.22 the effect of the zero tracking function can clearly be seen. It raised the zero point by 1 g for weights 50 through 68, lowered it by 1 g 1 minute later for weights 69 through 86 and then raised it again by 1g for the next minute. For weights 171 through 206 the zero point was raised and remained unchanged for 2 minutes. Although these were still grouping errors, the effect on accuracy was small negligible.

Test 9.2: Manufacturer suggested settings with greater punnet mass

In order to ensure that a greater object mass would not affect the accuracy of mass measurements as shown by test 2.4, in Figure 6.10, test 9.1 was repeated with a heavier punnet. The result is shown in Figure 6.23 and Table 6.4. This test had a slightly better accuracy than test 9.1, which could be due to the smaller sample used in test 9.2.

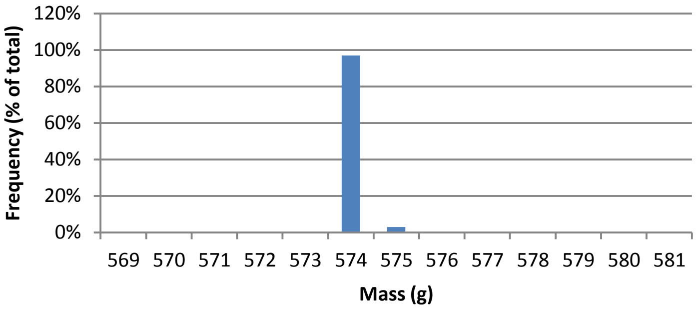


Figure 6.23: Test 9.2 Manufacturer suggested settings: heavier punnet mass distribution

The decision, at the end of the factory tests, to keep the manufacturer’s suggested setup as optimal for the check weigher remained unchanged and all experiments to follow used the same parameter setup, unless stated otherwise.

6.4 Punnet rejection test results and discussion

The punnet rejection test consisted of two parts: A test for rejection at the lower mass limit and a test for rejection at the upper mass limit. These tests were conducted at the factory.

The rejection test was based on the optimal parameter settings achieved in test 4. The lower limit was set to 525 g gross punnet mass and the upper limit to 575 g gross punnet mass. For the rejection test at the lower limit a 524 g punnet was weighed 100 times and for the upper limit a 576 g punnet was weighed 100 times. The results for the respective tests are shown in Table 6.5, and the mass distributions in Figure 6.24. Both were normally distributed.

Table 6.5: Punnet rejection tests' results

Test	Mean	Mode	Standard deviation	Range	Within allowed variance
Lower limit	523,7g	524g	0,8g	4g	98,8%
Upper limit	575,9g	576g	0,7g	3g	99,8%

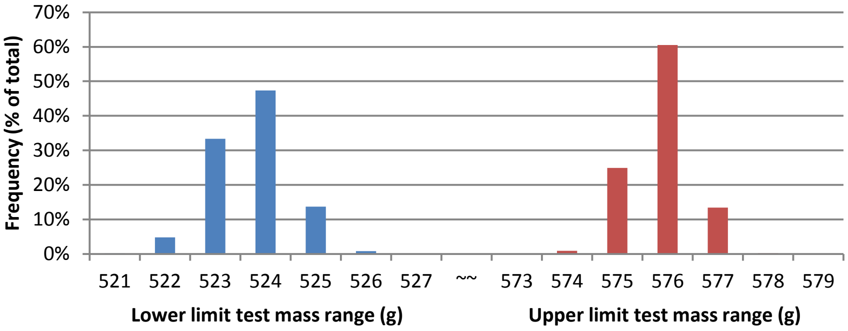


Figure 6.24: Punnet rejection tests' mass distributions

From normal curve probabilities, there is a 10,3% chance at the lower limit that a 524 g punnet would not be removed from the packing line by the check weigher, and a 0,6 % chance that a 523 g punnet would not be removed.

Likewise there is a 10,3 % chance for a 525 g punnet to be removed as an under mass punnet and a 0,6% chance for a 526 g punnet to be removed wrongfully.

At the upper limit a 576 g punnet has a 6% chance not to be removed as over mass and a 0,1% chance for a 577 g punnet, likewise a 574 g punnet has a 6% chance of being rejected as over mass and a 573 g punnet a 0,1% chance.

6.5 Conveyor level differences results and discussion

An influential factor in the accuracy of the check weigher is the dynamic stability of the punnet and its content during the weighing period on the load cell. A difference in the height levels of conveyor belts may result in less dynamic stability of the punnet and subsequently less accurate mass measurements. Height differences may occur during installation or by accident. The aim of this test was to determine the effect of height differences on the accuracy of the check weigher.

Height differences at two stages of the check weigher were investigated: Between the feeding and speed-up conveyors and between the load cell and faulty package separator unit conveyors. For the first test the feeding conveyor was set 10 mm higher than the speed-up conveyor as shown in Figure 6.25. The punnet thus fell onto the speed-up conveyor, taking longer than normal for the grapes to stabilise.

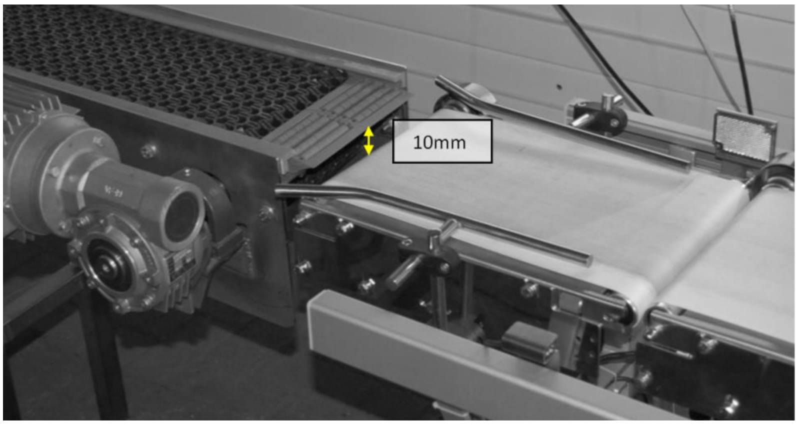


Figure 6.25: Height level difference between feeding and speed-up conveyor belts

The second test saw the feeding conveyor back at its normal level but the faulty package separator unit's conveyor 10 mm higher than the load cell conveyor, as shown in Figure 6.26. The punnet thus bumped into the raised conveyor before leaving the load cell.

Neither of the tests had any effect on the accuracy and distribution of the measured weights. The results were similar to those of factory test 5. The height difference between the feeding- and speed-up conveyor belts had no effect because enough time passed for the punnet to become dynamically stable and for the vibrations to be damped before the sampled mass measurements were collected. The height difference between the load cell and separator conveyor belts had no effect because all sampled mass measurements were collected before the punnet made contact with separator unit's conveyor belt.

No further tests were conducted on this subject, because the probability of a height level difference larger than 10mm occurring without being noticed is miniscule.

Figure 6.26: Height level difference between load cell and separator conveyor belts

6.6 Successive punnets results and discussion

Until now all of the tests comprised one punnet being weighed repeatedly with fixed cycle times. This test would serve as a simulation of a real-world implementation with successive punnets of different mass being weighed. The timing between the weighing of successive punnets would be investigated as well.

This test was conducted using the parameter settings of test 2.2 and thus the mass measurements were not as accurate as would have been when using the manufacturer's suggested settings from test 9.1. Three punnets were used, a 531 g, 544 g and a 557 g, hence the saw tooth pattern in Figure 6.27.

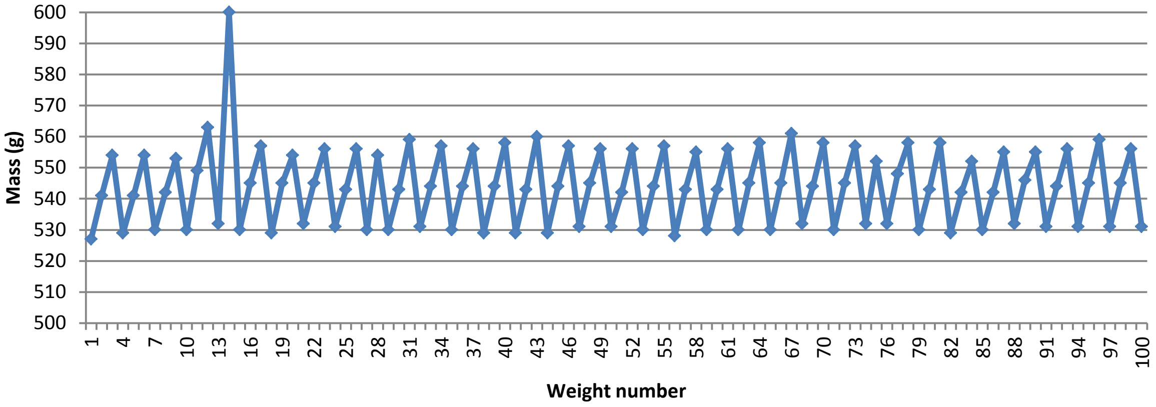


Figure 6.27: Successive punnet weights

For most of the time the three punnets' weights could be clearly distinguished from the pattern, except for weights 13 to 15, 27 to 29 and 74 to 76. In the first instance the second punnet's mass was much higher than usual and the third punnet was not weighed at all. In the second instance only the first and last punnets were weighed, and in the third instance the second punnet was too heavy and the third punnet was not weighed.

The observation of missed punnets and wrong weights could be explained with the help of Figure 6.28. The check weigher is only able to detect the next punnet once all the current punnet's sampled mass measurements have been collected. With 'T1' = 105, 'CollTimes' = 18 and the conveyor speed at 0,7 m/s it was calculated that successive punnets need to be more than 473 mm apart in order to be distinguished by the check weigher as different punnets. The first and third instances of weight exceptions are those explained by Figure 6.28.

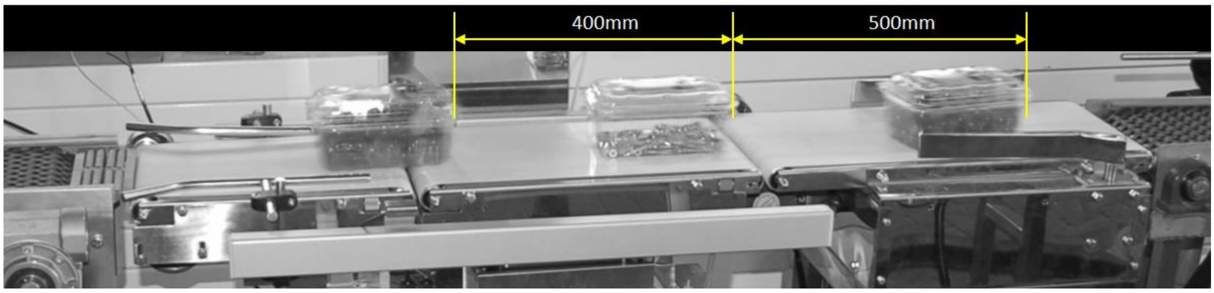


Figure 6.28: Distance between successive punnets

In the first instance the distance between punnet 1 and punnet 2 was sufficient to distinguish between the punnets, however punnet 3 was too close to punnet 2 and was not distinguished as a separate punnet. At some point both punnets were on the load cell while the mass of punnet 2 was still being sampled. The third instance was similar to the first one, but only a small part of punnet 3 was on the load cell while punnet 2 was being weighed.

In the second instance punnet 2 was less than 473 mm behind punnet 1, but more than 445 mm, refer to Figure 6.4. Therefore punnet 2 was not on the load cell while the mass of punnet 1was being sampled.

For ‘T1’ = 130 and ‘CollTimes’ = 4, as chosen for the optimal setup, successive punnets may not be less than 478 mm apart. In order to be safe, the speed of the feeding conveyor must be such that successive punnets can never be less than 500 mm apart after being sped up onto the check weigher.

The check weigher conveyor moves at 42 m/min or 700 mm/s. With punnets a minimum distance of 500 mm apart, the check weigher can handle up to 1,4 punnets per second, or 5 040 punnets per hour. It is possible to increase the check weigher speed, but that would result in a decrease in accuracy.

6.7 Conclusions

This chapter has described experiments with the check weigher parameter setup to achieve the accuracy of ±2 g as stated by the manufacturer. The check weigher was then tested for known sources of disturbance and the maximum feed rate was determined.

The check weighers used in the productivity study in Chapter 5 had the default factory parameter setup. An accuracy test was conducted in a factory by weighing a single punnet repeatedly. The results for the default parameter setup are given in Table 6.6. After much experimentation and consultation with the manufacturer, the optimal parameter setup was found, with the results given in Table 6.6.

Table 6.6: Check weigher parameter setup results

Parameter setup	Range (g)	Standard deviation (g)	Percentage within ±2 g (%)
Default	7	1,6	79,8
Optimal	3	0,7	99,8

During the factory tests certain disturbances were noticed, some of which could be attributed to the automatic zero tracking function, but the causes of others were unidentified. In order to isolate the disturbances, the tests were repeated in a controlled environment at a laboratory. The laboratory tests results were similar to the factory results, but more accurate with less variance. The unidentified disturbance at the factory is believed to be due to low frequency vibration in the floor, due to machinery and moving vehicles. Similar vibrations could be expected in a pack house and therefore the factory results were a good representation of a real world implementation.

Rejection tests at the upper and lower mass limits, using the optimal parameter setup, determined that there was a 10,3% chance for punnets with a mass 1 g below the lower limit, to qualify and pass the check weigher. This would be a much better result than was achieved with the default parameter setup, and should surely decrease the number of under mass punnets further.

Experiments with conveyor level height differences showed that this did not affect the accuracy of mass measurements at all, although the punnets were damaged, and the quality of the contents could possibly be affected by bruising of the berries.

A test to determine the maximum punnet feed rate for the check weigher showed that the accuracy was very sensitive to following distance. If punnets were too close together, the second punnet would not be weighed and the first punnet's mass could be too high. It was determined that a safe following distance would be 500 mm, measured from the front end of punnet *n* to the front end to punnet *n+1*. This meant that the check weigher could handle up to 5 040 punnets per hour accurately.

This chapter has shown that the check weigher satisfies all the requirements set for check weighing (step 1.3.3.2, Determine the requirements for automated check weighing and step 1.3.3.3, Determine if the check weigher satisfies the requirements). Use of the optimised parameter setup as determined by the experiments, would also increase the effectiveness of the check weigher in eliminating punnets of incorrect mass.

7. Conclusions and recommendations

The goal of this thesis was to evaluate the use of check weighing as tool to enhance the operational effectiveness of table grape punnet packing. This would be accomplished by: Determine the state of table grape punnet packing in South Africa; Determine the operational effectiveness of current packing practices; and Evaluate automated check weighing as an operational management tool.

This chapter will summarise how the research goal was accomplished and will reach a conclusion. It will also present recommendations for improvement and further studies.

7.1 Conclusion

The state of table grape punnet packing in South Africa was determined by completing steps 1.3.1.1 through 1.3.1.4 (see Section 1.3.1):

Agriculture constitutes only 3% of the gross national product in SA, but more than 16% of the population is either directly or indirectly dependent on it for employment and income. The table grape industry exports most of its produce, with the main destinations being the EU and the UK. A high demand for pre-packaged products has been reported in the EU and UK, following a change in consumer requirement towards more convenient and hygienic products. However, the European markets are under pressure from the economic downturn and the demand for pre-packaged fruit is growing at a very slow pace. SA has also started exporting to emerging markets in the Middle East, Far East and Asia, where the need for pre-packaged fruit is still developing, as consumers become more health conscious and start to require more convenient products.

SA's biggest competitor for market share is Chile and, although SA is physically closer to the European markets, it cannot be as competitive as Chile due to factors such as the cost and low skill level of labour. The table grape industry is largely dependent on seasonal labour; seasonal labourers often have a limited formal education and are associated with many social problems. These factors may impair their ability to perform quality work and to produce high quality products.

The quality requirements for pre-packaged table grapes are determined by the consumer and are ensured through various different quality standards. An external PPECB inspector confirms the physical quality of finished products by inspection of random samples before they leave the pack house.

As a sub-sector of agriculture, table grape punnet packing is very important to the country, because of its labour intensiveness. The labour intensiveness can also be the impairing factor in the delivery of high quality products that satisfy the high demand for punnets as well as the consumer requirements.

The operational effectiveness of current packing practices was determined by completing steps 1.3.2.1 through 1.3.2.5 (see Section 1.3.2):

Six systems were found to be commonly used for punnet packing in SA; some of the systems had internal check weighing functionality and some also had target punnet mass functionality. The productivity and accuracy of five of these systems were investigated during the productivity study. Productivity was measured in punnets produced per man-hour, counting all personnel in the pack house. This allowed the systems to be compared on the same basis. Systems based on lean principles such as less handling of the product during preparation showed the best productivity, exceeding the company target almost every day.

The accuracy of a packing system was determined by its ability to produce punnets with the smallest variance from the target punnet mass, using the least amount of mass bandwidth. The better the accuracy of the system, the smaller are the chances of producing under and over mass punnets. The results varied among the systems from very good to very poor accuracy and showed that some systems could definitely benefit from external check weighing.

Conventional quality control comprises an internal Quality Inspector conducting random quality checks on finished punnets, checking for numerous quality attributes, including punnet mass, and taking corrective action if any defects are found. In the needs assessment survey producers reported the occurrence of under mass punnets during internal quality checks to be between 1% and 3%. External quality control is conducted by the PPECB in a similar manner by checking random samples. PPECB reported that about 5,7% of all inspected table grape products were found to be under mass, indicating a problem with the conventional internal mass quality checks.

If a PPECB inspector finds more than two defective punnets per pallet, that pallet has to be repacked, at considerable loss to the producer. Pallets can also be rejected at the local ports or upon arrival at the foreign markets due to under mass punnets, at great loss to the producer.

Punnet packing systems vary greatly in productivity and accuracy, but because total final product check weighing by hand is not always possible, they could all benefit from automated external check weighing to make them more effective while producing products of higher quality. The financial implications of packing under mass punnets could be severe, in terms of losses to the company.

Automated check weighing was evaluated as an operational management tool by completing steps 1.3.3.1 through 1.3.3.5 (see Section 1.3.3):

An operational management tool is any process or system that can increase the operational effectiveness of a company within its continuous improvement strategy. Check weighing could be used as an operational management tool to improve the quality of the products produced and, by keeping record of punnet weights, also enable a company to produce punnets for the average mass system. This could potentially open new markets for the company and allow them to save on product giveaway, thereby increasing their operational effectiveness.

To produce punnets complying with the average mass system, a check weigher must be able to determine the mass of a punnet to within 3 g and keep records of the mass of all the qualifying punnets. The check weigher investigated in this study was a modular unit, capable of storing mass records on a remote PC. In the productivity study the default parameter setup for the check weigher was used, but experiments showed that using those parameter values did not produce very accurate results. New parameter values were found, giving the check weigher an effective accuracy of ±2 g.

During the productivity study, feedback data from the company's UK operation was used to determine the effect of check weighing. Punnets are check weighed in the UK and the data is used as pro-active customer feedback. Data from before the date that check weighing was implemented in the pack house was compared with data after check weighing was implemented. Check weighing managed to reduce the number of under mass punnets by an average of 2,9% and the over mass punnets by 5,51%; however, 3,29% of punnets were still under mass. Some of the punnets of incorrect mass could be blamed on upper and lower mass limits in the pack houses and at the UK operation being different.

A generic payback period was calculated for the expense of implementing automated check weighing at any size pack house with any layout. It was based on the occurrence of under mass punnets as stated in the needs assessment survey (1%), the financial loss of having to repack a rejected pallet at the pack house (R10 000) and the cost of a new check weigher (R90 000). It was calculated that the financial payback period would be acceptable for larger producers, as well as for small producers, given that they have only one packing line.

Although check weighing was not able to remove all under mass punnets using the default setup of the system, it did show an improvement and would surely be more accurate with the new parameters. Check weighing is an ideal operational management tool for increasing operational effectiveness in the punnet packing industry, when used in conjunction with the packing systems.

7.2 Recommendations

Although the new check weigher parameters were tested during the experiments in a simulated environment, no real-world application results are available for the new parameters. It is recommended that a follow-up study be conducted to compare the results of using the new check weigher parameters with the results from the 2011/2012 season.

A repeat of the needs assessment survey could also be conducted, after presenting producers with the facts about check weighing and its benefits, as well as the payback period calculations. It would be interesting to note whether they would change their minds about implementing check weighing.

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9. Appendices

Addendum A: Journal Article

Addendum B: Conference Article

Addendum C: Needs assessment survey

Addendum D: Check weigher operating manual

Addendum A. Journal Article

TABLE GRAPE PUNNET PACKAGING: THE INFLUENCE OF CHECK-WEIGHING

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ABSTRACT

Most of South Africa's table grapes are exported to the EU and the UK. In recent years, pre-packaged table grapes are now preferred in many European supermarkets. This increased demand has resulted in stringent quality standards, including the specification of punnet mass. Locally, table grapes are packed manually using seasonal labour, who often have limited formal education. Punnets must conform to upper and lower mass limits, but many deviations occur due to human and machine error. Check-weighing proved effective in reducing out-of-specification punnets, but human and machine errors were still problem factors.

OPSOMMING

Die meeste Suid-Afrikaanse tafeldruiwe word uitgevoer na die Europese Unie en die Verenigde Koninkryk. Die voor-verpakking van tafeldruiwe in 'punnets' begin al meer voorkeur geniet by Europese supermarkte. Hierdie verhoging in aanvraag het gelei tot strenger gehaltestandaarde, insluitend 'punnet' massa. In Suid-Afrika word meestal gebruik gemaak van seisoenale werkers met beperkte formele onderrig om tafeldruiwe te verpak. 'Punnets' moet voldoen aan boonste en onderste massagrense, maar baie deviasies kom voor as gevolg van menslike- en masjienfoute. Geoutomatiseerde eksterne toetsweging lewer positiewe resultate ten opsigte van vermindering van oor- en ondergewig 'punnets', maar menslike- en masjienfoute bly steeds probleemfaktore.

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1. INTRODUCTION

Despite concerns about packaging material wastage [1, 2], the display space devoted to pre-packed fruit and vegetables in European supermarkets, and the sale of pre-packed products in the United Kingdom, have increased -by 70% and 71% respectively during the past decade [3]. Most of South Africa's table grapes are exported to these countries [4]. Currently, only 30% to 40% is pre-packed in transparent 500g containers known as punnets, but the growing demand is driving a change towards punnet-packing [5, 6, 7].

Punnet-packing is labour intensive, and quality assurance is a major challenge. The supplier must take into account a 2% to 3% mass loss due to a reduction in moisture content during shipping [8], to ensure a net mass of at least 500g for each punnet upon arrival overseas, when packing to the minimum system. Alternatively, an average mass of 500g per batch of 1,200 punnets with a tolerable negative error of 15g per punnet must be ensured when packing to the average system [9, 10]. Sampled quality inspections are performed at the inland pack houses and on arrival overseas [11, 12]. Under-mass punnets may lead to the rejection of a pallet containing 1,200 punnets. The upper mass limit depends on the producer, and an optimal ratio of productivity-to-oversupply beyond specification – referred to as 'giveaway' – needs to be found.

Several systems are available for packing grapes into punnets. All systems rely on humans to do the work, and all have some means to assist the packer to achieve the correct mass. None of these are, however, entirely error-proof. In an effort to eliminate underweight punnets and to limit 'giveaway', producers have started implementing external check-weighers, as well as replacing old systems with new ones featuring mandatory internal check-weighing.

During the 2011/2012 packing season, four different systems employed by three large grape pack houses were evaluated. The four systems are described in the following section. The data sources and data gathering methodology are explained in section 3. The results are presented and discussed in section 4, followed by the conclusion in section 5.

2. BACKGROUND

In order to ensure complete customer satisfaction in a mass production environment, the quality of all products must conform to the required quality standards [13, 14]. In the grape packaging industry, all possible steps are taken to ensure quality during production [15], but in the end, the quality of finished products is dependent on humans. The only way to ensure that all products leaving the pack house comply with minimum quality standards is through 100% final product inspection [16]. Check-weighing can, however, be used to inspect one of the key quality parameters, that of punnet mass.

Punnet packaging systems were evaluated during this study. Three were existing systems with external check-weigher modules added before the beginning of the packing season, and one was a new system with integrated internal check-weighing only. Internal check-weighing refers to the built-in functionality of a punnet packaging system to perform check-weighing on punnets; and external check-weighing refers to the addition of an automated external check-weighing module to the existing system. Table 2.1 gives a summary of the four systems.

Table 2.1: Punnet packaging systems implementation

Punnet packaging system	State of system	Internal check-weighing capability	External check-weighing module added
Generic scale system	Existing system	No	Yes
Local storage combination system	Existing system	Yes	Yes
Conveyor system	Existing system	Yes	Yes
Computer-supported scale	New system	Yes	No

The different punnet packaging systems and check-weighing methods are discussed in the rest of this section, as well as the causes of error. For the systems with an additional external check-weighing module, the systems are discussed in their basic form without the external check-weigher. Figure 2.1 shows the symbols used in the process flow diagrams to describe the systems.

Figure 2.1: Symbols used for process flow diagrams

2.1 Punnet packaging system: No internal check-weighing

The generic scale system using the hand-packing method is described in Figure 2.2. It is often referred to as the guess-and-cut method, and can be difficult for labourers with a limited formal education to master. According to studies, this method could be cognitively exhausting for workers with limited education due to the monotony of the task [17] [18]. The generic scale system is the most labour intensive method, and requires rather intensive management to be successful [19]. This method does not have any technology-supported built-in check-weighing functionality, as the only feedback is the mass shown on the scale display. Packers are instructed which mass values to use for upper and lower mass limits, and are assumed to conform.

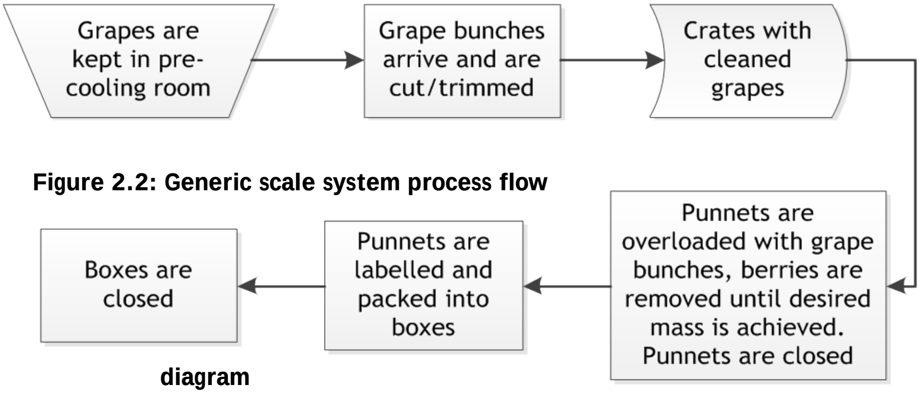

Figure 2.2: Generic scale system process flow diagram

2.2 Punnet packaging system: Internal check-weighing

Many of the existing punnet packaging systems incorporate some type of internal check-weighing system. These internal check-weighing systems rely on, or make assumptions about, the human operators and the dynamics of the grape supply, therefore making them prone to errors [16].

In addition to the normal upper and lower mass limits, the three systems in this section also have a target mass parameter. The system will aim to produce punnets with a mass closest to the target. The local storage combination system and computer-supported scale system make use of dynamic target mass adjustment. In the local storage combination system, the mean fill-mass is kept as close to the target as possible by dynamically adjusting the upper limit to push the band of permitted mass either upwards or downwards towards the target mass. In the computer-supported scale system, both the lower and upper limits are simultaneously adjusted to keep the allowable bandwidth constant [20].

The local storage combination system consists of a vertical storage rack with a microcontroller-based scale on each side, featuring dynamic target mass adjustment. Figure 2.3 describes the operation of this system. The two sides are integrated using common in-process storage. For optimal operation, three people are required on each side. The three workers on each side switch position throughout the day and cross-check each other's work [17].

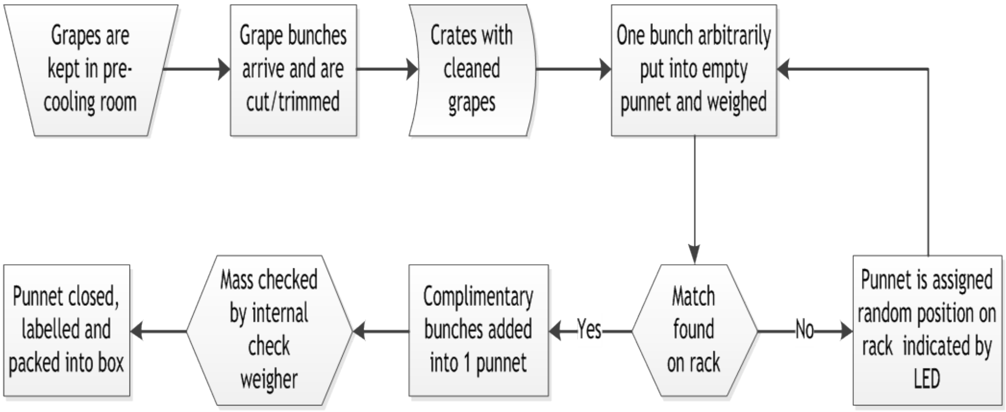

Figure 2.3: Local storage combination system process flow diagram

Because of the monotony of the task, errors are bound to occur [18]. This creates a need to remove the possibility of human error from the system [16]. This system therefore has an internal poka-yoke type error-recognition system that recognizes an incorrect punnet before it is finished [21], and that is independent of lapses in the operator's attention span [22]. After the contents of the two complimentary punnets have been added together, the internal check-weighing function verifies that the net mass of the punnet is within specification, and a green go-ahead light is activated on the display. However, it is still dependent on the operator/packer to execute his task as instructed.

The conveyor system is a computerised horizontal conveyor combination system, described in Figure 2.4. The system runs at high speed, and packers need to be constantly alert not to miss a bunch or pick up the wrong bunch. This system's internal check-weighing is based on combinations made by the computer, and assumes that packers do not make mistakes and that no loose berries fall from bunches when picked up from the cups. The check-weighing function gives no feedback to the packers.

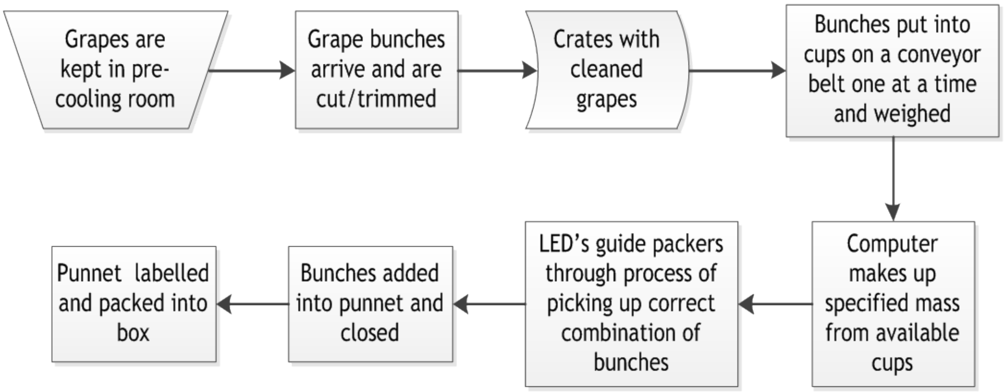

Figure 2.4: Conveyor system process flow diagram

The computer-supported scale system is a new entry into the South African market. It is a computer-based scale-assisted hand-packing system with dynamic target mass adjustment, as described in Figure 2.5. Each scale dynamically adjusts its target mass and assists the packer by means of LEDs to achieve approximately the desired punnet mass. When a punnet with a mass outside the lower or upper limits is removed from the scale, the functional type internal poka-yoke [22] check-weigher locks the user interface, and a supervisor code must be entered to continue operation.

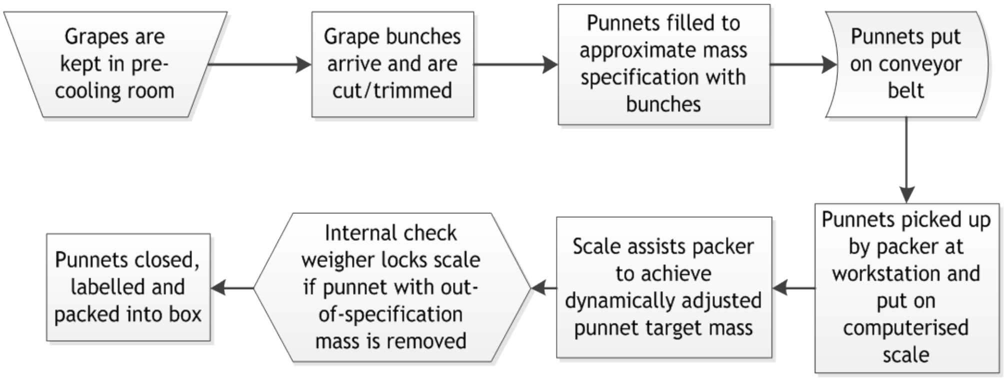

Figure 2.5: Computer-supported scale system process flow diagram

2.3 Punnet packaging: Causes of error

According to Kolarik, there are two types of manufacturing errors: machine errors and human errors [23]. Most machine errors occur as a result of the incorrect set-up of a system. The various causes of error are discussed in this section. It is clear that the punnet packaging systems reviewed have some inherent opportunities for human error.

All the systems discussed in sections 2.1 and 2.2 require an initial set-up at the beginning of the day, or after being restarted during the day. With the generic scale system, the scales need to be tared with an empty punnet in order to ensure the correct net mass. The set-up of the other systems investigated is somewhat more complex, requiring setting up of the lower and upper mass limits as well the target mass.

Most machine errors occurred when scales were not tared correctly during the initial set-up, or when the tare button was accidently pressed during operation. When using the generic scale system, only one scale is affected, and in most cases results in below-mass specification punnets. If the operator does not notice this, he or she could unknowingly be producing below-mass specification punnets [24]. When using the local storage combination system, a tare error on one or both of the scales will result in wrong combinations. If only one scale has a tare error, the other scale's built-in check-weighing system will show that many combinations have an out–of-specification net mass, and the operator will realise that errors are occurring and alert a supervisor. A tare error in the computer-supported scale system will continue producing under-mass specification punnets if not noticed by the packer or supervisor.

With the conveyor system, berries that fall from bunches when handled are left behind in the cups, and can result in underweight punnets. Berries protruding from punnets may get dislodged before the punnet is closed, resulting in under-mass punnets.

The Yerkes-Dodson human performance curve depicted in Figure 2.6 [25] shows that performance is related to the levels of arousal, stress, and anxiety experienced. It is difficult to determine the level of stress or arousal that results in acceptable performance because it differs between individuals [23]. In the pack house setting, the level of stress and anxiety can become rather high, especially just before lunch and later in the afternoon when the amount of grapes in the pre-cooler is perceived to be an insurmountable task for the day. (The general practice is that grapes should be packed on the same day that they are picked.) Workers become exhausted by the monotony and by their standing position [18]. Human errors mostly occur during these periods.

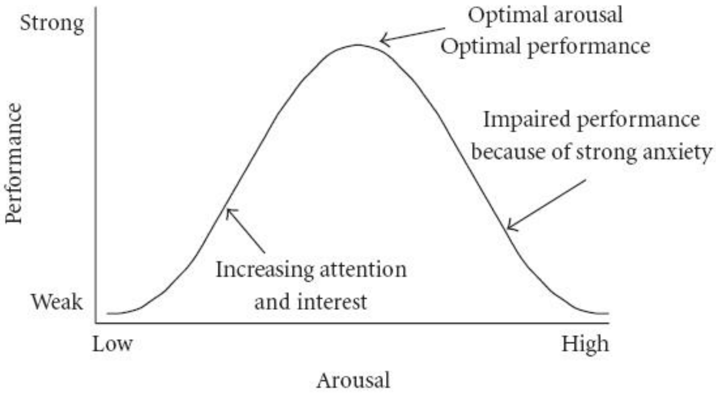

Figure 2.6: Yerkes-Dodson human performance curve [25]

Kolarik defines a human error as an out-of-tolerance action, where limits of acceptable performance are defined by the system [23]. Two types of human error apply to grape punnet packaging: errors of omission, where part of a task is omitted; and errors of commission, where a task is performed incorrectly. In all four punnet packaging systems, packers repeat the same actions over and over throughout the day, and with the local storage combination system in particular, they tend to develop shortcuts for some actions in order to work faster. The built-in check-weighing function is often judged to be an optional extra step that can be omitted to save time without affecting the operation of the system. When performance is below acceptable limits, the probability for human error increases [26], and it often happens that a punnet is accidently put into a wrong position on the rack, or that a command to put a punnet on to the rack is confused with a command to add two punnets together. With the conveyor system, the same problem occurs when packers add wrong bunches together, or when loose berries are left behind in the cups. Although the computer-supported scale system locks the user interface in the event that a punnet with out-of-tolerance mass is removed, it is still up to the packer to recheck the mass of the punnet, and sometimes this step is omitted with the out-of-tolerance punnet put on the conveyor line instead. These two types of errors combined could result in a large number of under- and overweight punnets.

From this discussion it is clear that the current solutions for packing punnets are not mistake-proof, and that success ultimately relies on the human operators performing their task correctly and not circumventing built-in error-correction functionality. These operators, however, are mostly seasonal workers with a limited formal education and low level of numeracy [27, 28]. This proves to be a challenge in the mistake-proofing process. An automated 100% mass check of the final product could ensure that no punnets with out-of-tolerance mass go through the process undetected.

2.4 External check-weighing module and integration

An external, independent check-weigher can be added to an existing system with minimal change to the infrastructure [22]. The check-weigher used in the evaluation is a modular system comprising a load cell-and-conveyor belt combination with control panel and controller, as well as a separate faulty package rejection unit to remove the punnets with out-of-specification mass. The unit is shown in Figure 2.7.

Figure 2.7: Automated external check-weighing module

Although the check-weigher is fully automated, it still relies on a human to set it up and to ensure that the air pressure for the pneumatic rejection unit is adequate.

3. DATA COLLECTION

During the 2011/2012 packing season, data from the four different systems described above was collected by collating the check-weigher data and by extracting stored data from the computer controlled system.

For validation of the results, a comparison was made with information from the company’s UK operation. Upon arrival in the UK, the open-top punnets are flow-wrapped. During this process the punnets are check–weighed [1, 11, 29]. Two sets of data from the 2010/2011 and 2011/2012 packing seasons were obtained from the UK.

4. RESULTS AND DISCUSSION

To facilitate comparison, 2,5% was subtracted from the net mass at production to compensate for moisture loss during shipping.

4.1 Punnet mass distribution

Data collected and analysed during the 2011/2012 season, with more than 65,075 punnets of grapes packed, display distinct differences between the packing systems studied. The generic scale packing technique shows a distribution skewed towards the upper limit in Figure 4.1, with an intuitive implication of increased giveaway.

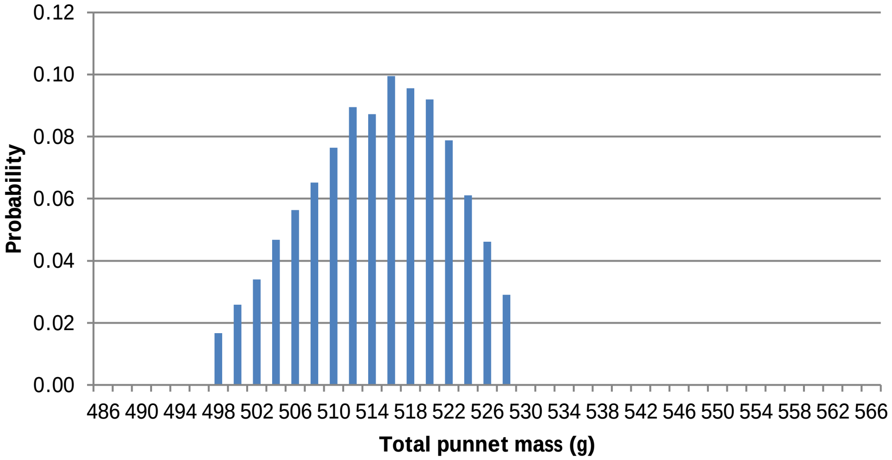

Figure 4.1: Generic scale system punnet net mass distribution

The local storage combination system, shown in Figure 4.2, displays a skewed distribution towards the lower limit. It indicates that the system's algorithm, which provides a target mass independent of the upper and lower limits, has a marked effect, with a positive influence on giveaway.

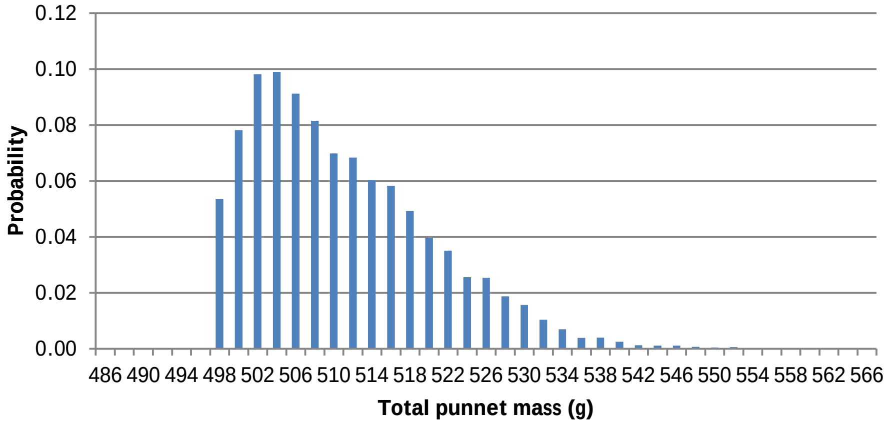

Figure 4.2: Local storage combination system punnet net mass distribution

The conveyor distribution system, as shown in Figure 4.3, indicates that this system also has a skewed distribution towards the lower limit. The distribution is also wider relative to the other systems tested, with a marked tail towards the upper limit.

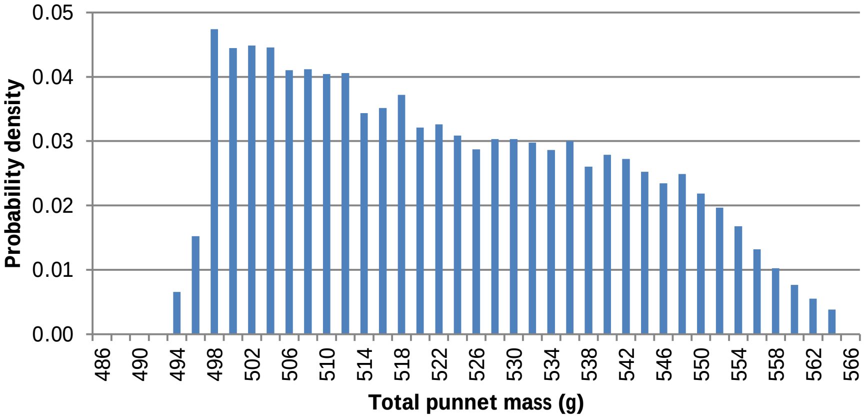

Figure 4.3: Conveyor system punnet net mass distribution

From Figure 4.1, the net mass of punnets when packed using generic scales has a mean (µ) of 513,3g, a standard deviation (σ) of 7,2g, and a mode of 515g. The clearly cut tails at 498g and 528g correspond to the mass limits of the external check-weigher. The punnet-packing process is totally random when using this system. Punnets can be made up of any arbitrary bunches as long as the resulting mass falls between the upper and lower limits. Although the limits for the packers were the same as on the check-weigher, 10,3% of the day's 13,042 punnets were rejected by the external check-weigher.

Figure 4.2 depicts the net punnet mass distribution for the local storage combination system. The mean (µ) is 509,8g, the σ is 9,2g, and the mode is 503g. This skew distribution can be attributed to the dynamic target mass function of the system, which aims to make a punnet combination closest to the target mass. The target mass was the same as the lower limit on the system – 497g. Therefore, at a mere 6g over target, the mode shows that the targeting functionality has an observable effect. The upper limit of this system was set higher than the generic scales because the operators were still new to the system, and a larger mass bandwidth makes it easier to use in the beginning. The check-weigher's limits were set up accordingly. Of the day's 12,847 punnets, 4,8% were rejected by the external check-weigher. This shows that the local storage combination system's internal check-weighing function is relatively effective, but that human error still exists.

The net punnet mass distribution for the conveyor system is shown in Figure 4.3 with µ 521g; σ 17,5g, and mode 496g. This system's standard deviation is approximately double that of the generic scale and the local storage combination systems. As it functions as a combination system with a limited storage area on the conveyor, throughput can be increased by extending the bandwidth. During data collection, the bandwidth was set to 71g to increase throughput further. Nevertheless, the mode of the distribution shows that combinations closer to the target mass of 491g indeed have higher priority. Of the day's 17,940 punnets, 4% were rejected by the external check-weigher.

According to its log, the computer-supported scale system produced 21,246 punnets on the particular day, with an average net mass of 502,2g, marginally higher than the 502g target mass. The dynamic target mass adjustment function implemented in this system is therefore effective. As the system does not have an external check-weigher, the punnet mass distribution is not available. However, the internal check-weigher uses the same system parameters to perform its task.

It therefore becomes clear that the check-weighers detected under-mass punnets caused by human or machine errors. In the next section, the feedback data from the UK is used as validation for the effectiveness of the check-weighers.

4.2 Validation by means of punnet mass feedback from UK

The punnet mass data from the UK sketches a clear picture of the effect of external check-weighing (generic scales, local storage combination system, and the conveyor system) and mandatory internal check-weighing (computer-supported scale system). The two sets of data from the UK are shown in Figure 4.4. During the 2010/2011 season, the generic scale, local storage combination, and the conveyor systems were the same as in the following year, but without integrated external check-weighers. In the last pack house a generic scale system was replaced by a computer-supported scale system for the 2011/2012 packing season. Since 2010 the emphasis on minimum and maximum punnet mass has increased, and has resulted in a lower and smaller allowable mass bandwidth. Lower limits were reduced to embrace the average system. The upper limits were set by the company as a target to reduce giveaway.

Feedback punnet mass data from the UK for the generic scale and local storage combination systems are depicted in Figure 4.4. From the graph it is clearly seen that 2011/2012 had improvements on every level following the addition of the external check-weighers. The large number of overweight punnets can be attributed to the pack house using a higher upper limit than in the UK. This was either a communication error, or the pack house manager deliberately decided to keep the mass bandwidth larger in order to increase the throughput. Although there has been a significant decrease in underweight punnets, they account for 2,8% of the total checked in the UK.

For the conveyor system, the feedback results are shown in Figure 4.4. Again, an increase in punnets with the correct mass is observed, but it is small compared with the increase seen for the generic scale and local storage combination systems. The small decrease in under-mass punnets could be because open top punnets were used, resulting in moisture loss greater than the 2,5% used for calculating the lower mass limit. The high number of over-mass punnets was a result of the high upper limit set for the system.

The feedback results for the computer-supported scale system are also shown in Figure 4.4. It is important to note that the 2010/2011 results were for a generic scale system that was replaced by a computer-supported scale system for the 2011/2012 season. A 12,2% increase in punnets of the correct mass was observed as a result of the decrease in over- and under-mass punnets. In spite of the 10,2% decrease, 7,7% of the punnets were still over-mass. A possible reason could be that the supervisor’s code was entered to reset the internal check-weighing function warning without re-checking the punnet mass, if they realised that it was an over-mass error.

The continued occurrence of underweight punnets during the 2011/2012 season is attributed to human and machine errors, as described in section 2.3. As stated there, even though the check-weighing module runs fully automated, it still needs to be set up by a human. A typical example of this was when the air pressure for the rejection unit was not turned on during set-up, and although the check-weigher detected an under-mass punnet, the rejection unit could not remove it from the production line.

Proximity sensors are used to determine when there is a punnet on the load cell. A typical machine error occurred when one of the sensors was misaligned after being hit by a punnet. This caused the check-weigher to miss a large number of punnets – some of which possibly had an out–of-limit mass.

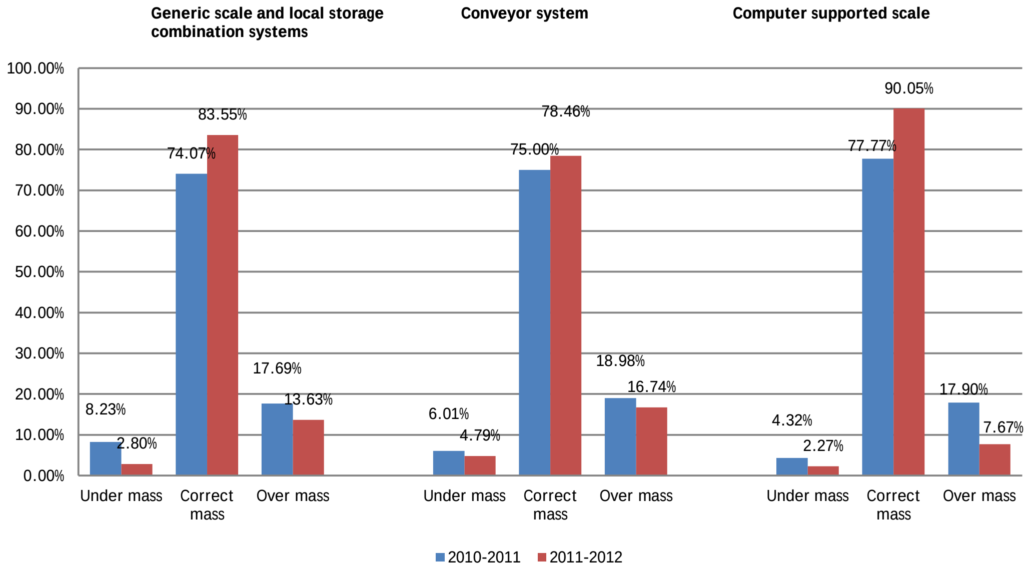

Figure 4.4: UK punnet mass feedback

4.3 Check-weigher cost analysis

In 2011 a survey was conducted on the occurrence of under-mass punnets and the associated penalty costs for rejected pallets [19]. Based on this, the cost implications for implementing check-weighing at the pack houses studied are calculated. The cost of having to repack an entire pallet, together with the loss of production and sale of another pallet, is estimated to be R10,000 (2011 prices). The cost of an external check-weigher module is R90,000, and the cost of a computer-supported scale system is R1,500,000. The total cost savings from a decrease in under-mass punnets is calculated using the total number of pallets produced at the end of the 2011/2012 season at each of the pack houses, and the percentage decrease in under-mass punnets for each. The payback period for the external check-weighers at each pack house was calculated in years or 'packing seasons'. The calculations are shown in Table 4.1.

Table 4.1: Check-weigher payback period calculation

Systems in pack house	Total pallets	Additional systems	Under-mass reduction	Potential savings	Payback period (DCF)
Generic scale and local storage combination systems	3,281	2 external check-weighers	5,43%	R 1,781,583	0,1 Years
Conveyor system	903	2 external check-weighers	1,22%	R 110,166	1,63 Years
Computer-supported system[1]	1,455	1 new system	2,05%	R 298,275	5,03 Years

[1] The cost considered for the computer-supported system is for the entire system and not only for the check-weighers, as in the other systems.

Without even considering the positive financial effect of a reduction in over-mass punnets (and the resultant increase in sellable product), the external check-weighers will have covered their costs in potential savings within two years. Furthermore, this is well within the benchmark for capital recovery of five years that is typical for this industry. Hence, the addition of external check-weigher modules makes sense from a quality improvement point of view, as well as from a financial point of view. A computer-supported scale system will cover its costs in savings in just over five years.

5. CONCLUSION

Product quality in a table grape pack house is dependent on humans, no matter which system is used for the packaging process. Mass quality deviations are attributed to two kinds of errors: machine and human. Some machine errors are actually attributable to human errors and are avoidable. Others can be discovered and rectified during regular inspection. Human errors are attributed to two factors: negligence and sub-optimal performance. Negligent errors can be avoided, or at least discovered soon after occurrence, by providing sufficient training. Errors due to sub-optimal performance will be difficult to avoid because it is impossible to keep all workers at optimal performance throughout the day.

The only way to eliminate the effect of human errors on punnet mass is to do a 100% mass quality check. Three of the four systems used to pack punnets feature internal check-weighing functionality, but it is possible for the operators to omit or bypass these functions during production. Automated external check-weigher modules were added to the generic scale, local storage combination, and conveyor systems. These remove all punnets with out-of-specification mass from the production line. The computer-supported system features mandatory internal check-weighing. Unfortunately this solution is not mistake-proof either, because it is not automated, and needs to be used correctly by the human operators.

Results show that systems with internal check-weighing had fewer punnets rejected by the external check-weighers than the system without internal check-weighing; therefore internal check-weighing does make a positive difference. Feedback data from the UK was used to evaluate the effect of external check-weighers. Data from the 2010/2011 season, before external check-weighers were installed, and from the 2011/2012 season following the installation, was used. Results show increases in punnets having the correct mass as well as decreases in over- and underweight punnets following the installation of external check-weigher modules.

In a customer-driven environment, where continuous improvement of quality is an industry as well as a company goal, an average increase in mass quality from 75,6% to 84% is significant. The cost of quality can also be controlled as shown in Table 4.1 costs can be limited by merely adding and integrating an external check-weigher to the current infrastructure. The alternative is to replace an existing system with a whole new one featuring mandatory internal check-weighing, at considerable capital expense. The study shows that the 100% mass quality goal could not be met, but the additions of the external check-weighing modules and mandatory internal check-weighing are both in line with the company’s continuous quality improvement strategy, and have contributed positive results.

Further punnet mass quality improvements could be achieved by making the set-up of the external check-weighers more robust, and making it more difficult to omit or bypass the internal check-weighing functionalities of the packing systems. More extensive training, with an emphasis on mistake detection, could be given to help operators and packers discover mistakes early in the production line and rectify them. Checklists for operating the packing systems, as well as for setting up the external check-weighers, could be implemented. For the external check-weighers, the proximity sensors could be upgraded for better punnet detection, and additional sensors could be added to monitor the air pressure for the separating arms. Clear communication of mass limits throughout the pack houses will also cause an increase in the number of punnets within the correct mass band by decreasing over-mass punnets.

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Addendum B. Conference Article

ECONOMIC REQUIREMENTS ANALYSIS FOR TABLE GRAPE CHECK WEIGHING

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ABSTRACT

South Africa's table grape industry exports most of its production to the developed world where customer satisfaction is very important and strictly regulated. Severe penalties are levied for underweight packaged products and contracts could even be lost. This study aims to determine the feasibility of automated check weighing of final product prior to shipping. The frequency of occurrence of underweight packages is investigated by means of structured interviews conducted within the industry. The probable financial impact of underweight packing is estimated and the paper concludes with a presentation of the capital amount producers can spend to eliminate underweight packaging profitably.

1. INTRODUCTION

In recent years an increase in the proportion of table grapes exported in pre-packaged punnets has been observed. Penalties for underweight punnets are severe. Micro-managing punnet packaging is an option but does not suit the industry due to its labour intensiveness. The technology of check weighing punnets in motion is a possible solution but imported systems are rather costly.

The goal of this study is to determine the feasibility of automated check weighing of final product prior to shipping and the capital amount producers in the different enterprise size categories can spend to eliminate underweight packaging profitably.

The study makes use of structured interviews to determine the occurrence of underweight punnets, an analysis thereof and ultimately an estimate of the economic value that a producer will gain from such an investment to avoid such occurrences.

2. BACKGROUND

2.1. Export Trends

South Africa is currently ranked fourth in the world for table grape exports and the second largest in the southern hemisphere. Over the past three years export accounted for some 85% of its total table grape harvest [1]. Of this 58% was exported to the EU market and 22% to the UK market during the 2010/11 season.

The demand for pre-packaged table grapes in the EU and UK has shown steady growth during recent years [2]. Market research by the Centre Technique Interprofessionnel des Fruits et Legumes (CTIFL) determined that pre-packaged products occupied on average 70% of the total fruit and vegetable rack space in France [3]. Table grape producers have however been slow to adapt and the market for 500g punnets was under-supplied during the 2010/11 season [4].

2.2. Packing Technology

The 500g punnet is the most popular size for pre-packaging table grapes in South Africa. On average 10 punnets fit into a carton and 115 cartons make up a pallet, or unit. A punnet contains two or three bunches of grapes. To compensate for weight loss and the limitations of hand packing, 500g punnets are generally packed to between 520g and 570g. Four major methods of packing table grapes into punnets are used [5], [3]. (i) Punnets can be packed by hand using the guess-and-cut method described in Figure 2.1. (ii) It can be packed with the assistance of a horizontal lane sorting combination system as described in Figure 2.2. (iii) A microcontroller based combination rack system such as the one from Ergopak shown in Figure 2.3 can be used and lastly there is the option of (iv) a computerized horizontal conveyor combination system such as Vizier's grape sizing system described in Figure 2.4 [6].

The exact implementation of the different methods may vary somewhat from user to user but the basic principles remain the same.

Final product check weighing systems such as the one from Dantec are available in South Africa at a cost of approximately R90 000.

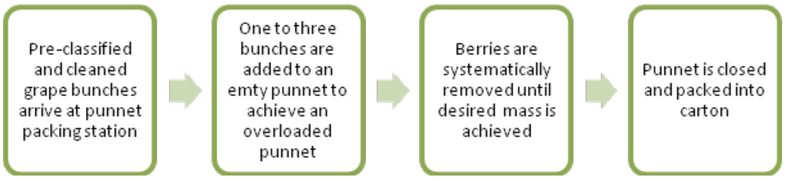

Figure 2.1 Punnet packing by hand

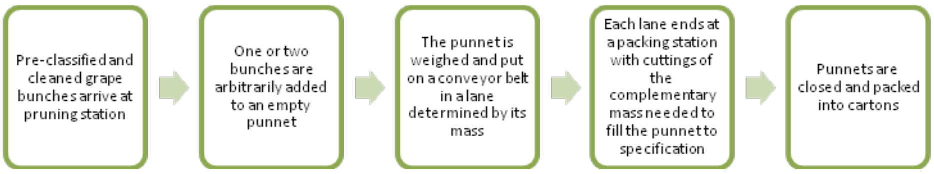

Figure 2.2 Lane sorting assisted method

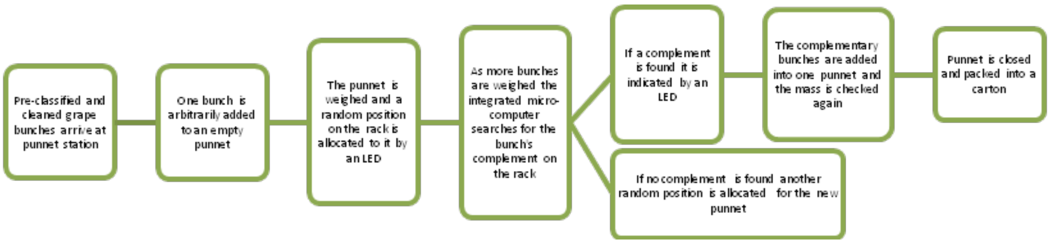

Figure 2.3 Microcontroller based combination method

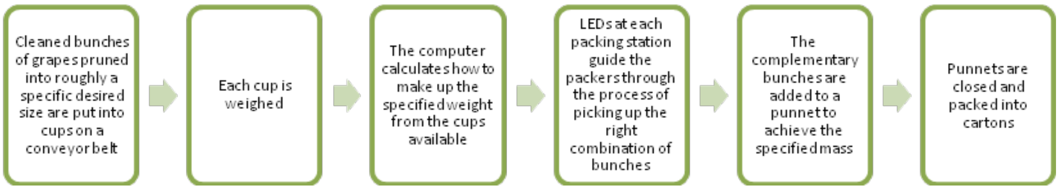

Figure 2.4 Computer based horizontal conveyor combination method

2.3. Quality Control Standards

Different quality control standards apply to farms producing products for export. The combination of standards depends on the client exported to. The standards determine different quality aspects for products including mass specifications. Figure 2.5 depicts the different quality standards and the percentage of interviewed producers they apply to.

Hazard Analysis and Critical Control Point (HACCP) is a food safety management system focused on preventing hazards, [7]. GlobalG.A.P. is a global set of voluntary standards for Good Agricultural Practices [8]. It serves as technical communication platform for continuous improvement and transparency across the entire food chain. The British Retail Consortium's (BRC) Global Standard-Food assists retailers to fulfil their legal obligations and protects the consumer by providing a basis to audit the supplier [9]. Tesco Nature's Choice is a prerequisite for supplying to Tesco, promoting only the best agricultural practices, [10]. The Perishable Products Export Control Board (PPECB) is a statutory organization controlling all perishable exports from South Africa, [11]. PPECB inspectors visit pack houses daily during the packing season to enforce the minimum specifications for export. All of these standards incorporate the ISO 9001 quality standard in some way. This standard specifies requirements for enhancing customer satisfaction by assuring continual improvement of the product, [12].

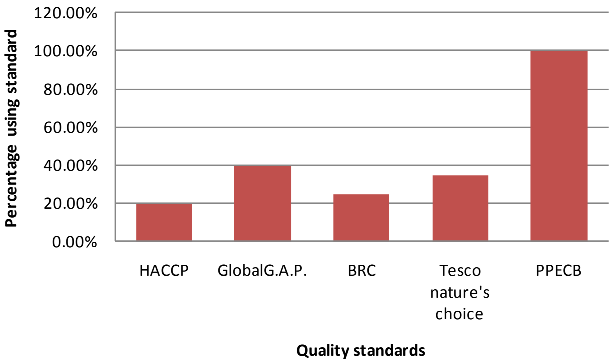

Figure 2.5 Quality standards used by producers

3. RESEARCH METHODOLOGY

This study was conducted among a randomly chosen group of 20 producers producing punnets and 3 export companies by means of structured telephonic interviews in order to investigate the different pack house situations.

4. RESULTS AND DISCUSSION:

4.1. Export trends

The market for punnet packed table grapes is still young and not fully exploited. The packaging methods are still in the early adoption stage of the respective technologies and where they are implemented, the approach is cautious. PPECB stated in an interview that only about 60% of table grape producers produce punnets. The results from the interviews are shown in Figure 4.1. 75% of the interviewed producers are exporting between 20% and 50% of their harvest as punnets. Only 10% export less than 20% and 15% export more than 50%.

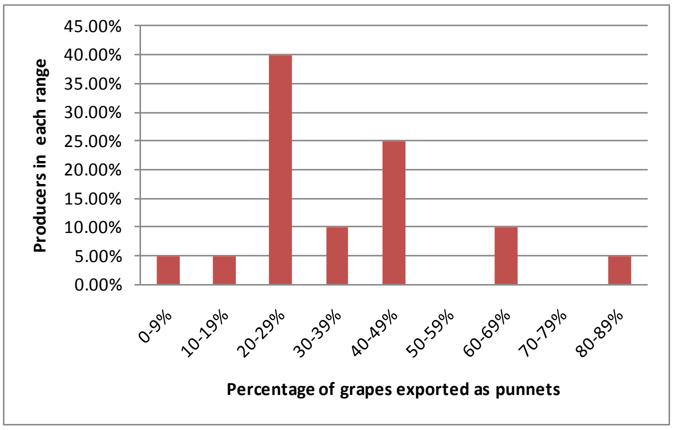

Figure 4.1 Punnet producer export trends

These results support the statement that producers are reluctant to produce punnets, particularly when the result above is compared to the French CTIFL study, reporting 70% prepackaging (Refer par 2.1). Possible reasons include the labour intensity of punnet packing, the higher cost of packaging material and the complexity of the packing method [5].

4.2. Packing technology and implementation

The different packing technologies used by the interviewed producers are shown in Figure 4.2. The implementations are described in the following paragraphs.

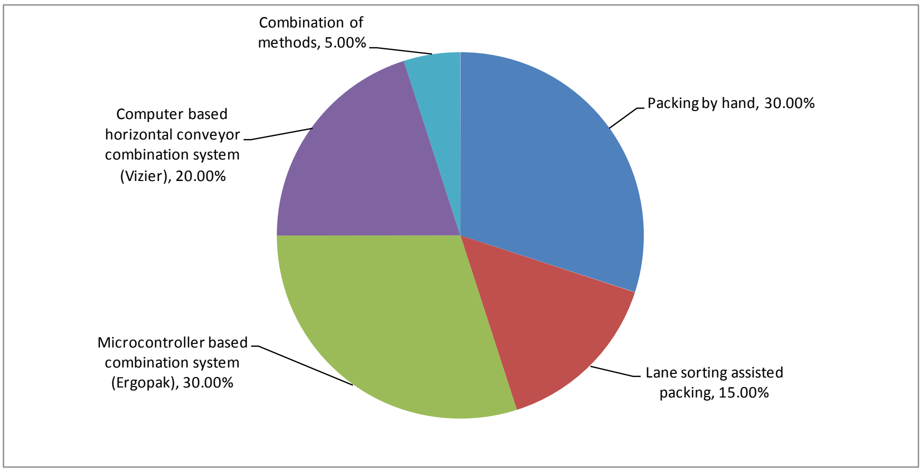

Figure 4.2 Packing technology used

4.2.1. Packing by hand

The method of packing by hand is described in Figure 2.1. It is often referred to as the guess-and-cut method and can be difficult for labourers with a limited formal education to master. According to studies this method is also cognitively exhausting, [3]. Packing by hand is the most labour intensive and requires rather intensive management to be successful. Another factor associated with the method is waste. The removed berries cannot be exported. This proportion of the grapes causes lost sales representing a cost increase factor when the market is under supplied. Figure 4.2 show that 30% of the interviewed producers are still using this method.

Producers using this method report giving a medium to high level of training to the punnet packers. This involves identifying the most able workers and giving them pre-training and job specific training. On some farms the export companies provide the training, but mostly it is provided by the producer’s own human resource department. Some producers conclude the training with a formal competence evaluation. Approximately 50% of the workers, predominantly seasonal, return year on year.

Management of the punnet packaging generally consists of a supervisor over each packing line. In some cases each packing station has a leader who coordinates the efforts of the other packers in the team.

4.2.2. Lane sorting assisted packing

The lane sorting assisted packing is described by Figure 2.2. This is the lowest cost machine aided method available and does not solely rely on the abilities of the packers.

Figure 4.2 shows that 15% of the interviewed producers employ this method. All of these producers provide pre training and job training during the season for the most promising workers that are selected for the punnet packaging. Workers are trained to be systematic in order to reduce errors. This system is generally well managed. Usually each lane system has a supervisor who constantly performs quality and productivity control.

4.2.3. Microcontroller based combination system (Ergopak)

Each punnet station comprises a vertical rack and a microcontroller-based scale on each side. Figure 2.3 describes the operation of the system. The two sides are integrated using common in-process storage. For optimal operation three people are needed on either side.

Research has proven the system to be effective and have a high productivity to capital cost ratio, [3]. According to Figure 4.2 30% of the interviewed producers use this system. It is relatively easy to use but requires training and guidance in the beginning. All producers provide pre–season training, on the job training or both. Many of the workers return each year. In the beginning the stations are managed closely but as the team's experience grows, the need for supervision diminishes. The three workers on each side switch positions throughout the day and cross-check each other's work.

4.2.4. Computer based horizontal conveyor combination system (Vizier)

This is the most capital intensive option for packing punnets and is described in Figure 2.4. Cambray explains that bunches input to the system need to be cut to roughly the desired size to work effectively [6]. Packers also need to be alert not to miss bunches allocated to them because the system runs at high speeds. When used effectively this system delivers a capacity three times higher than packing by hand [5].

Because it is a large and high capital cost system, it is generally more attractive to the larger producers. The survey results in Figure 4.2 show that 20% of the interviewed producers use this system. These are intensively managed by a supervisor for each system. The workers receive pre-season training at the training centre and on the job if any problems arise. Many are recurring workers and also act as mentors for the new ones.

4.3. Quality control

4.3.1. Internal quality control

Quality management in a pack house is done by the Quality Controller (QC). Normally the QC's are trained by the producers, but in some cases the export companies do their own QC training. QC's constantly monitor the quality of the products at different steps of the process. This includes punnet weight. If any problem arises the QC has to document and attempt to correct it. Most pack houses have well developed traceability practices enabling a deviance from the quality standard to be traced back to a person or packing station.

Underweight punnets can occur due to human error, a scale that is not set up correctly or a berry being lost from a bunch when handled. Scales are normally tarred twice a day or more and pack houses are kept at high humidity to prevent loose berries. Since the sources of errors are random, underweight punnets occur stochastically. For calculation purposes it is represented as a percentage of produced punnets.

QC's arbitrarily take cartons from the production lines and check the contents for the correct weight. Between 1% and 10% of cartons are checked. On average between 1% and 3% of the samples are found to be underweight when packing by hand or using the lane sorting system. The problems are traced back and corrective action is taken. A personal interview with a QC revealed the frequency of errors when packed by hand to be about 20%. This was inconsistent with the data given by management. It is the author's opinion that in general, where management is not working closely with the QC's, they are ill informed because of the "nobody wants to be the bearer of bad news" syndrome or subconsciously they want difficult to manage situations to be less severe. The study indicates that the actual frequency of underweight punnets is higher than originally stated. With the Ergopak and Vizier systems, the occurrence of errors is high in the beginning but as the packers' experience grows it reduces to the order of 1%.

Some other ways to minimize errors are to increase the management and quality control or to increase the mean weight of punnets. One producer effectively managed a mere 15g (about 3 berries) variation in punnets packed by hand and each finished punnet is weighed again to ensure quality. By increasing the punnet weight range by 20g on a lane sorting system another producer nearly eliminated the need for weight quality control.

4.3.2. External quality control

External quality control by the PPECB is mandatory. In some cases inspectors from the exporting companies or the client also do quality control from time to time. PPECB inspectors are required to inspect at least 2% of exported cartons. Cartons are arbitrarily chosen from finished units and all of the contents checked for correct weight. If one defect is detected, more sample cartons are checked. If two or more are found, all the punnets in a unit (pallet) have to be checked and corrected where necessary. If no more are found, only a warning is given. Some clients have a zero tolerance policy and if one defect is found, all punnets have to be checked.

External quality control acts as a good test to the effectiveness of the internal quality control. Producers implementing good internal quality control and stringent management had little to no units rejected by an inspector. Rejection frequencies varied from zero to 8% for all the producers. Quality control checks are also done at the ports prior to shipping and on arrival overseas. The export company Capespan reported less than 1% of exported units rejected overseas.

4.4. Economic penalty

When a unit, typically a pallet of 1150 punnets, is rejected at the pack house all its punnets need to be checked and repacked if defective. This consumes a large amount of time that could have been used to produce more punnets. The defective punnets also require new packaging material when being repacked. Producers estimate the physical cost of repacking to be between R200 and R800 per pallet. When the loss of production of a potential unit is added, the amount can be as high as R10 000 as shown in Figure 4.3. Rejects are therefore rather sent to alternative markets with lower quality standards, than repacked.

Rejected units at a local port are usually sold to the local market with lower specifications instead. When rejected overseas there are a few options. Units can be sent to a different market as lower quality for a much lower price than originally intended. Alternatively units can be repacked at considerable cost or units can be dumped. The revenue loss associated with a different market could typically be up to R4 500. Repacking costs are between 30 and 40 Rand per carton equating to about R4 000 per unit. When dumping a unit, it costs approximately R20 per carton of 10 punnets for the dumping plus approximately R80 income lost per carton. This equates to R11 500 per unit lost. These alternatives are depicted in Figure 4.3. Additionally, the probability of a possible loss of a contract due to frequent defects is high.

The interviews revealed overweight packing as a less obvious, but serious error on the production side, for example by giving away 10% extra grapes per punnet, one carton is lost for every ten packed. This adds up to more than R1000 per pallet. If a punnet is too full the contents bruise easily during handling and quality problems may arise.

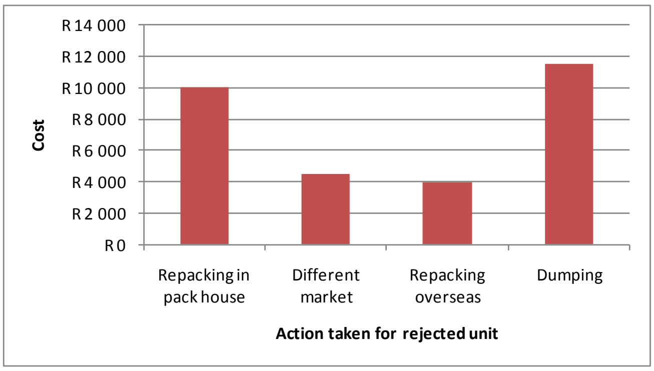

Figure 4.3 Cost of different actions taken for rejected units

5. CONCLUSION

The purpose of this paper is to determine the economic viability of an automated final product check weighing system in the pre-packaged table grape industry. From the interviews it was clear that underweight punnets do occur and often result in units being rejected at pack house level or further down the logistics chain. There was also evidence that a producer effectively eliminated underweight punnets by having a worker weigh every single package.

When asked about the implementation of a check weighing system, many producers stressed the fact that their current layout would have to be changed. This is surely a challenge and would have to be considered during the design. Smaller producers claimed that buying more than one system would also not be economically viable. An adaptation would have to be considered in order to implement one system to more than one packing line.

When calculating the period until a system will generate a profit, the occurrence of underweight punnets was taken as 1% of the total punnets produced. The number of probable rejected units was calculated for each interviewed producer and the cost of repacking a rejected unit was taken as R10 000. The number of systems required for each producer was calculated from data gathered during the interviews.

Figure 5.1 shows the time it will take in years, or packing seasons, before the system currently available at R90 000 generates a profit for each of the interviewed producers. This calculation only takes into account units rejected in the pack house based on prices for the 2010/11 season.

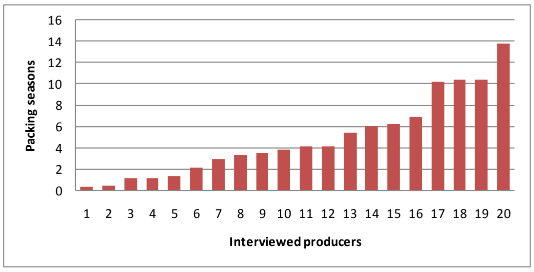

Figure 5.1 Years until system generates profit

On average the system will prove to be profitable within 5 packing seasons. The bigger producers will show profits much faster than the smaller producers. If packing lines could be incorporated as mentioned earlier, the times could almost be halved for some producers.

It is shown that the system will be economically viable if sold for less than R90 000 without considering the potential loss of a contract. Producers will be prepared to pay such an amount if presented with the facts. By adding a log keeping function to the check weighing system, units' mass can be certified and value is added to the product. This can also open doors to new markets. Should a market for punnets packed to an average mass be accessible, the check weighing system could prove invaluable in saving on overweight packages.

6. REFERENCES

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Addendum C. Needs assessment survey

1. How many punnets are exported, what % of total exports are punnets and what is the duration of the packing season?

2. How many punnet lines are in the pack house?

3. On average, how many punnets are produced per packing line?

4. What method is used for packing punnets?
   - ☐ Hand
   - ☐ Semi-automatic (e.g. Local storage combination system or Lane sorting system)
   - ☐ Automatically (e.g. Conveyor combination system)

5. What is the management structure of the pack house?
   - ☐ Only one general manager for the entire pack house
   - ☐ Separate manager for the punnet division
   - ☐ Specific supervisors for punnet packing

6. How intensively are packers trained?
   - ☐ Everyone gets training before the packing season
   - ☐ Single person gets training before packing season (He/she must train the other)
   - ☐ Everyone is trained on-the-job
   - ☐ One person is trained on-the-job (He/she must train the other)
   - ☐ No training

   Notes:

7. Are punnets only checked for mass by the external inspector?

☐ Yes
☐ No

7.1. If not, how often is it done?

7.2. If not, how often do under-mass punnets occur?

8. What quality standards must be met?

9. Which export company is used?

10. How many times a day does the inspector visit?

11. How often does the inspector find under-mass punnets?

12. What happens when under-mass punnets are found?

    12.1. Only one per pallet?

    12.2. Two per pallet?

    12.3. More than two per pallet?

13. What procedures must be followed if a pallet is rejected:

    13.1. Pack house?

    13.2. Local cold room?

13.3. Local port?

13.4. Overseas?

14. In terms of time, money and reputation, give an estimate of the financial implications if a pallet is rejected:

14.1 Pack house?

14.2 Local cold room?

14.3 Local port?

14.4 Overseas?

15. Will you benefit from an inline weighing system, weighing each punnet and removing under-mass punnets before they get packed onto pallets?

☐ Yes
☐ No

15.1. Elaborate...

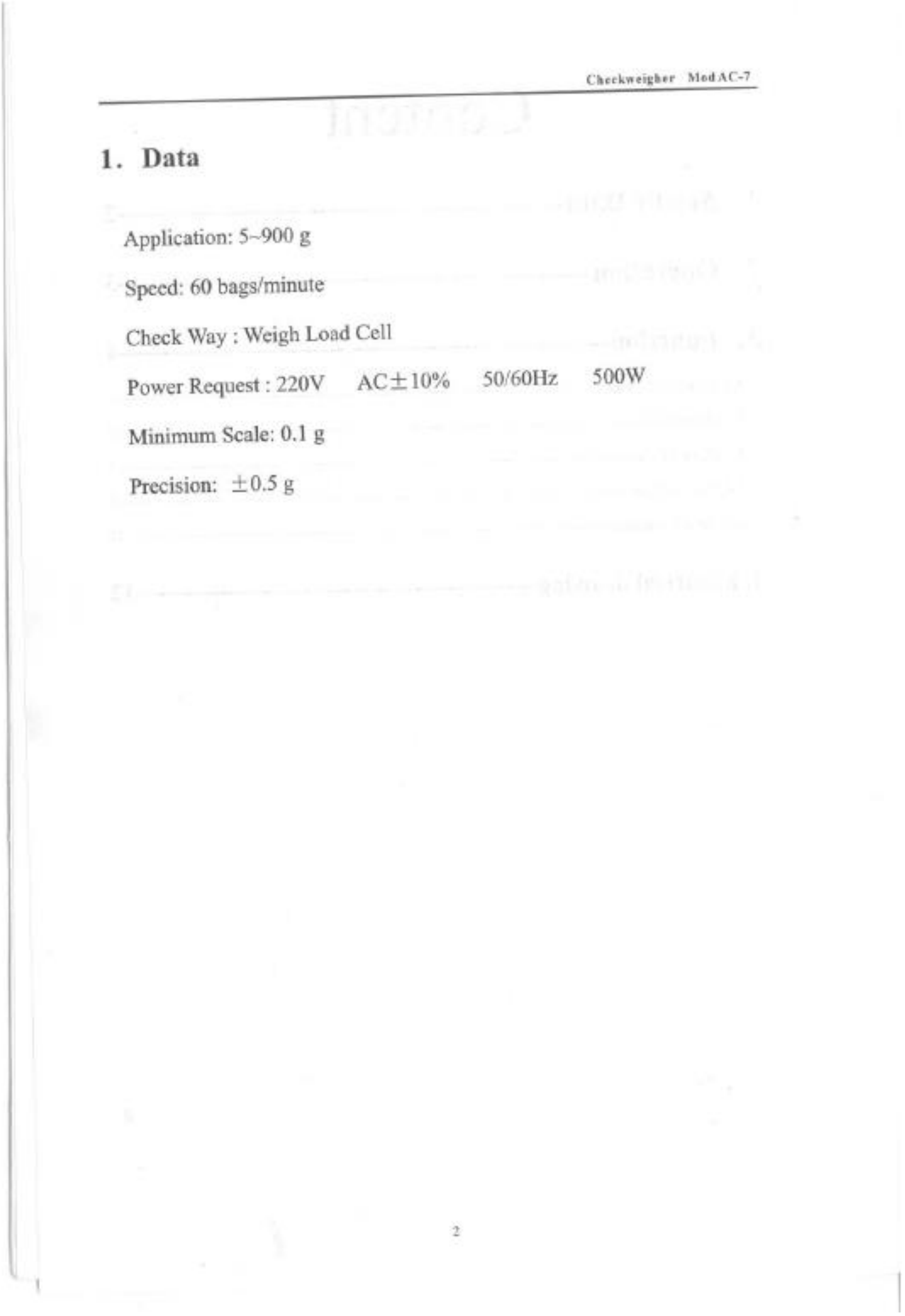
15.2. If yes, how much would you be willing to pay for such a system?

Addendum D. Check weigher operating manual

Checkweigher

Mod AC-7

Content



1. Data

Application: 5~900 g

Speed: 60 bags/minute

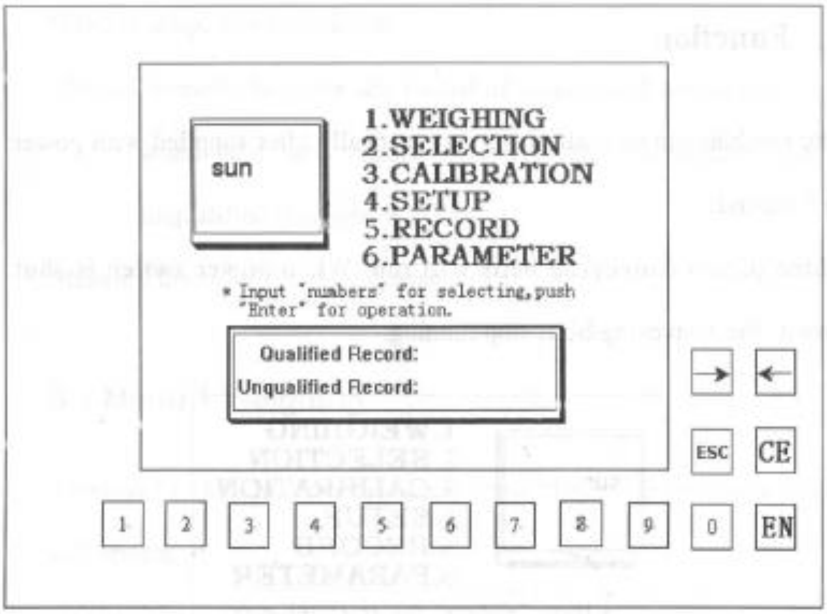
Check Way : Weigh Load Cell

Power Request : 220V AC±10% 50/60Hz 500W

Minimum Scale: 0.1 g

Precision: ±0.5 g

2. Operation



* Input "numbers" for selecting, push "Enter" for operation.

→ Cursor down

← Cursor up

ESC Return key (to cancel input or go back to main menu)

CE Clearance key (to clear previous datas)

0 9 Digital key

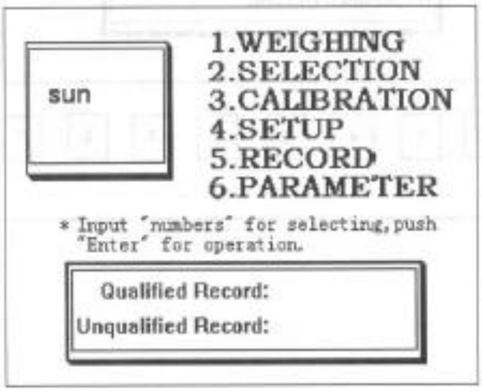
· Decimal Point

EN Enter key

3. Function

The machine enters main menu automatically after supplied with power in 5 seconds.

Three pieces conveying belts will run. When power switch is shut down, the conveying belts stop running.



* Input "numbers" for selecting, push "Enter" for operation.

Qualified Record:
Unqualified Record:

There is six menus for choice. Choose the menu you want and press the exact key. Press "EN" key, system will go into the menu chosen and function will come out.

Menu 1 Weighing: with weighing function like electrical weigher as well as zero clerance function, but without checking function.

Menu 2 Selection: Function of keeping qualified product, and record unqualified product.

Menu 3 Calibration: to calibrate the load cell.

Menu 4 setup: to set parameter

Menu 5 Record: To show the record of unqualified products (including when and how many products are unqualified, and the unqualified products' weight.

Menu 6 Parameter: To set up parameter.

3.1 Menu 1 Weighing

To press "1" key in main menu and press "EN", the following interface will appear:

SELECTION

000.0 g

Qualified Amount:

Unqualified Amount:

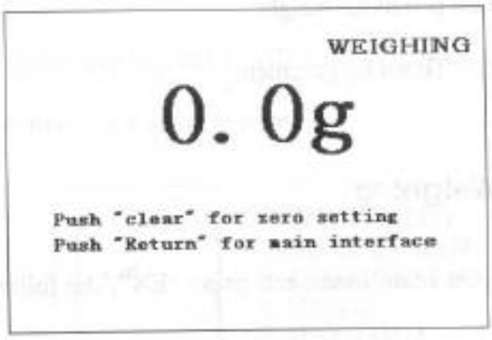
PresParaNum: TaWeight: g

ULWeight: g LLWeight: g

To show the weight of products which are on load cell. To press "CE" key to make zero clearance and press "ESC" key to quit.

3.2 Menu2 Selection

To enter into selection by pressing "EN"key .Make sure you have chosen the right parameter for the product, if current parameter is not right , please set correct parameter in function menu.



WEIGHING

0. 0g

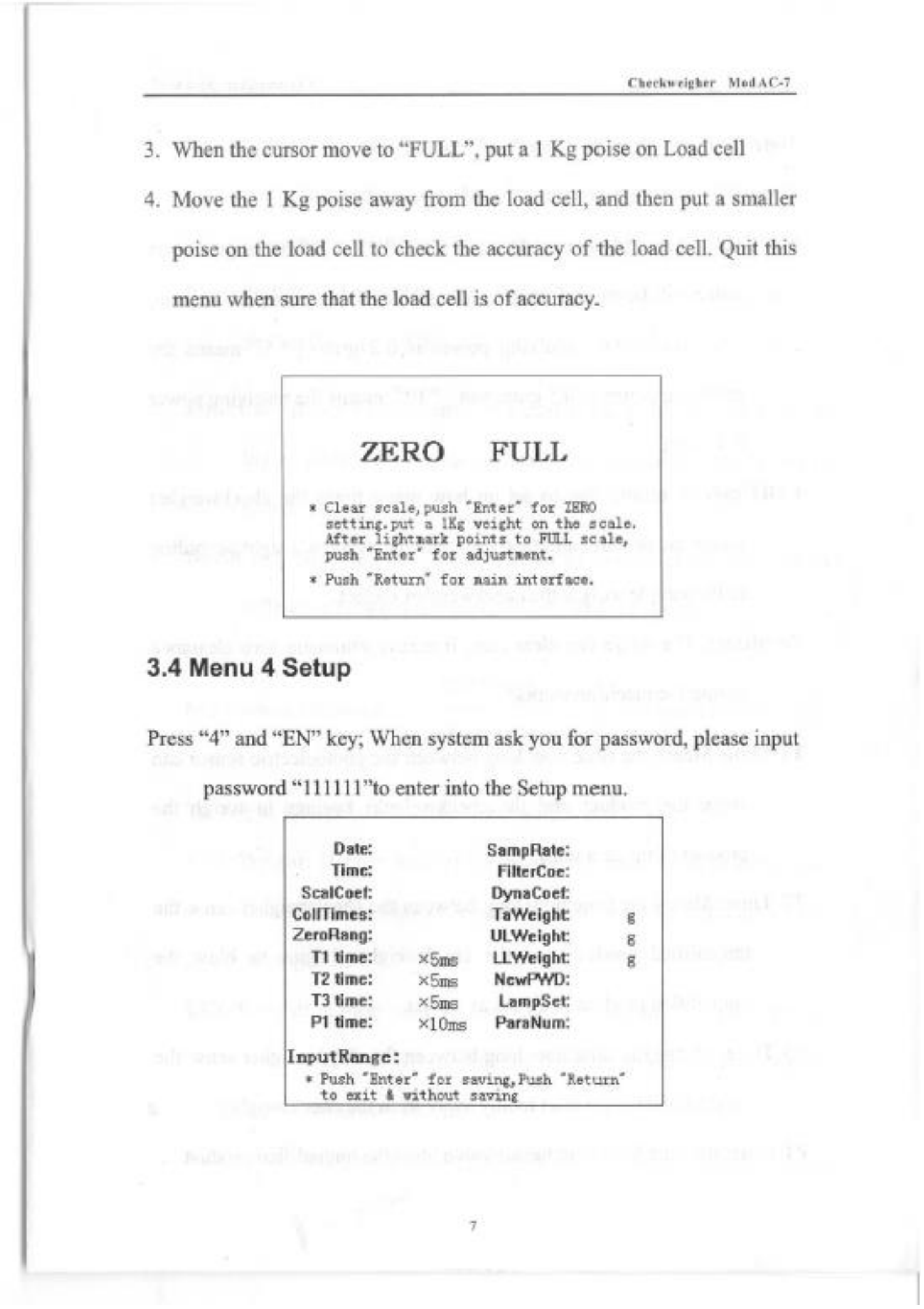
Push "clear" for zero setting
Push "Return" for main interface

To start checking function (let qualified products pass, and get rid of unqualified products)

3.3 Menu 3 Calibration

Press key "3" and key "EN" then input pass word "111111" to enter into the Calibration Menu.

1. To Stop the convey belt
2. To get rid of all things on the Load cell, have nothing staying on Load



3. When the cursor move to "FULL", put a 1 Kg poise on Load cell
4. Move the 1 Kg poise away from the load cell, and then put a smaller poise on the load cell to check the accuracy of the load cell. Quit this menu when sure that the load cell is of accuracy.

ZERO FULL

- Clear scale, push "Enter" for ZERO setting. put a 1Kg weight on the scale. After lightmark points to FULL scale, push "Enter" for adjustment.
- Push "Return" for main interface.

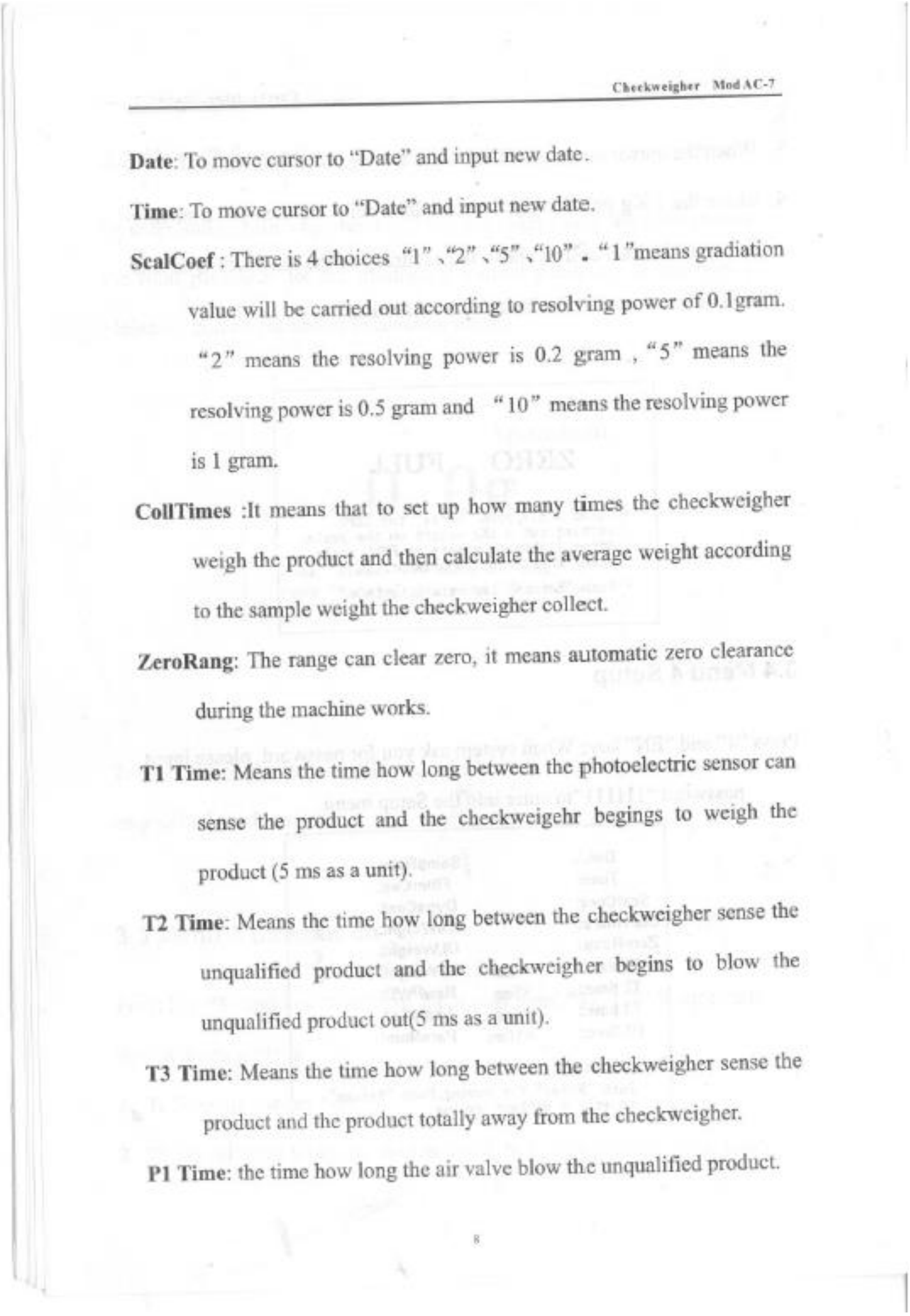
3.4 Menu 4 Setup

Press "4" and "EN" key; When system ask you for password, please input password "111111"to enter into the Setup menu.

Date:		SampRate:	
Time:		FilterCoe:	
ScalCoef:		DynaCoef:	
CollTimes:		TaWeight:	g
ZeroRang:		ULWeight:	g
T1 time:	×5ms	LLWeight:	g
T2 time:	×5ms	NewPWD:	
T3 time:	×5ms	LampSet:	
P1 time:	×10ms	ParaNum:	

InputRange:

- Push "Enter" for saving, Push "Return" to exit & without saving



Date: To move cursor to "Date" and input new date.

Time: To move cursor to "Date" and input new date.

ScalCoef : There is 4 choices "1"、"2"、"5"、"10"。"1"means gradiation value will be carried out according to resolving power of 0.1gram. "2" means the resolving power is 0.2 gram , "5" means the resolving power is 0.5 gram and "10" means the resolving power is 1 gram.

CollTimes :It means that to set up how many times the checkweigher weigh the product and then calculate the average weight according to the sample weight the checkweigher collect.

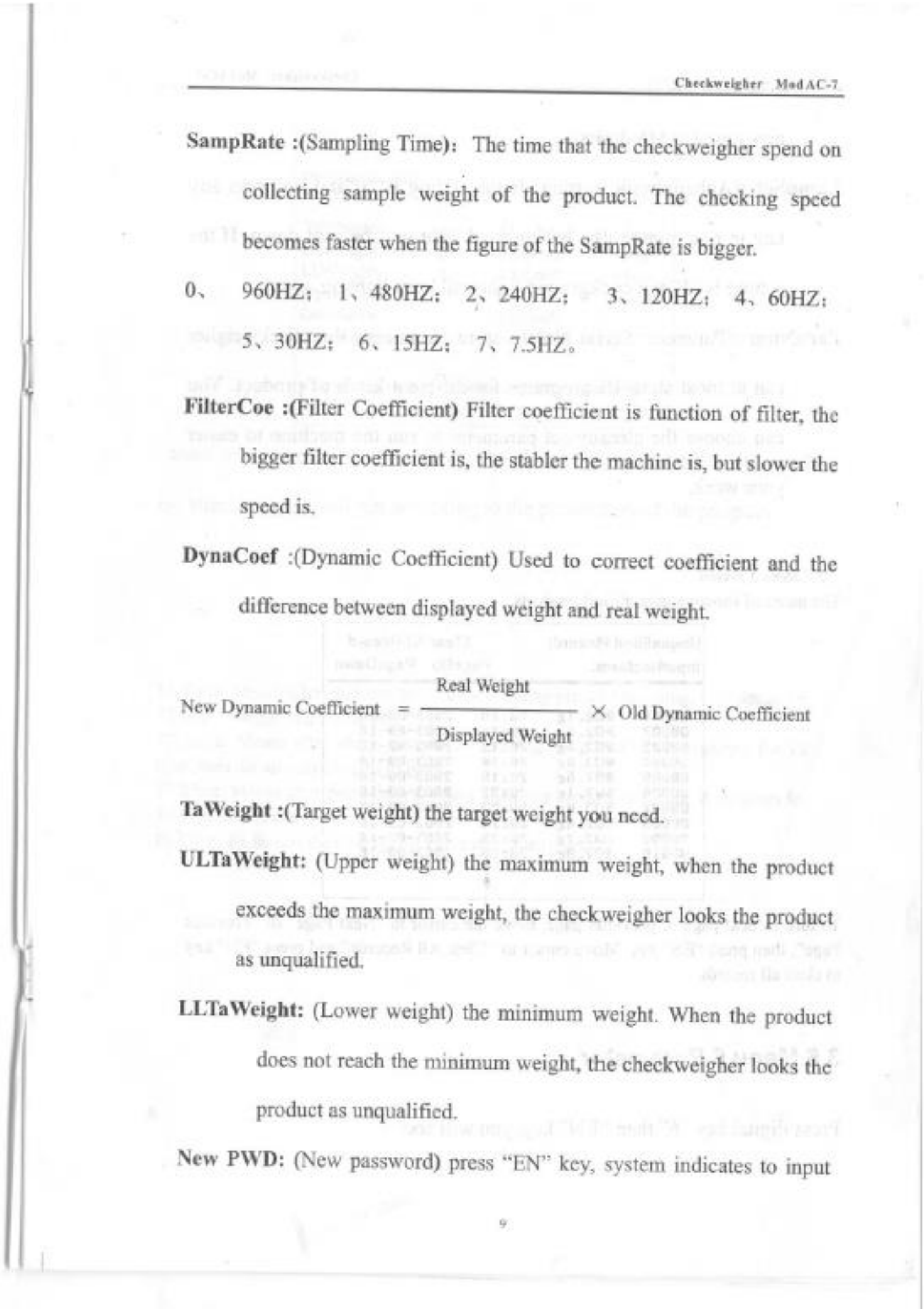
ZeroRang: The range can clear zero, it means automatic zero clearance during the machine works.

T1 Time: Means the time how long between the photoelectric sensor can sense the product and the checkweigehr begings to weigh the product (5 ms as a unit).

T2 Time: Means the time how long between the checkweigher sense the unqualified product and the checkweigher begins to blow the unqualified product out(5 ms as a unit).

T3 Time: Means the time how long between the checkweigher sense the product and the product totally away from the checkweigher.

P1 Time: the time how long the air valve blow the unqualified product.



SampRate :(Sampling Time)：The time that the checkweigher spend on collecting sample weight of the product. The checking speed becomes faster when the figure of the SampRate is bigger.

0、 960HZ； 1、480HZ； 2、240HZ； 3、120HZ； 4、60HZ；
5、30HZ； 6、15HZ； 7、7.5HZ。

FilterCoe :(Filter Coefficient) Filter coefficient is function of filter, the bigger filter coefficient is, the stabler the machine is, but slower the speed is.

DynaCoef :(Dynamic Coefficient) Used to correct coefficient and the difference between displayed weight and real weight.

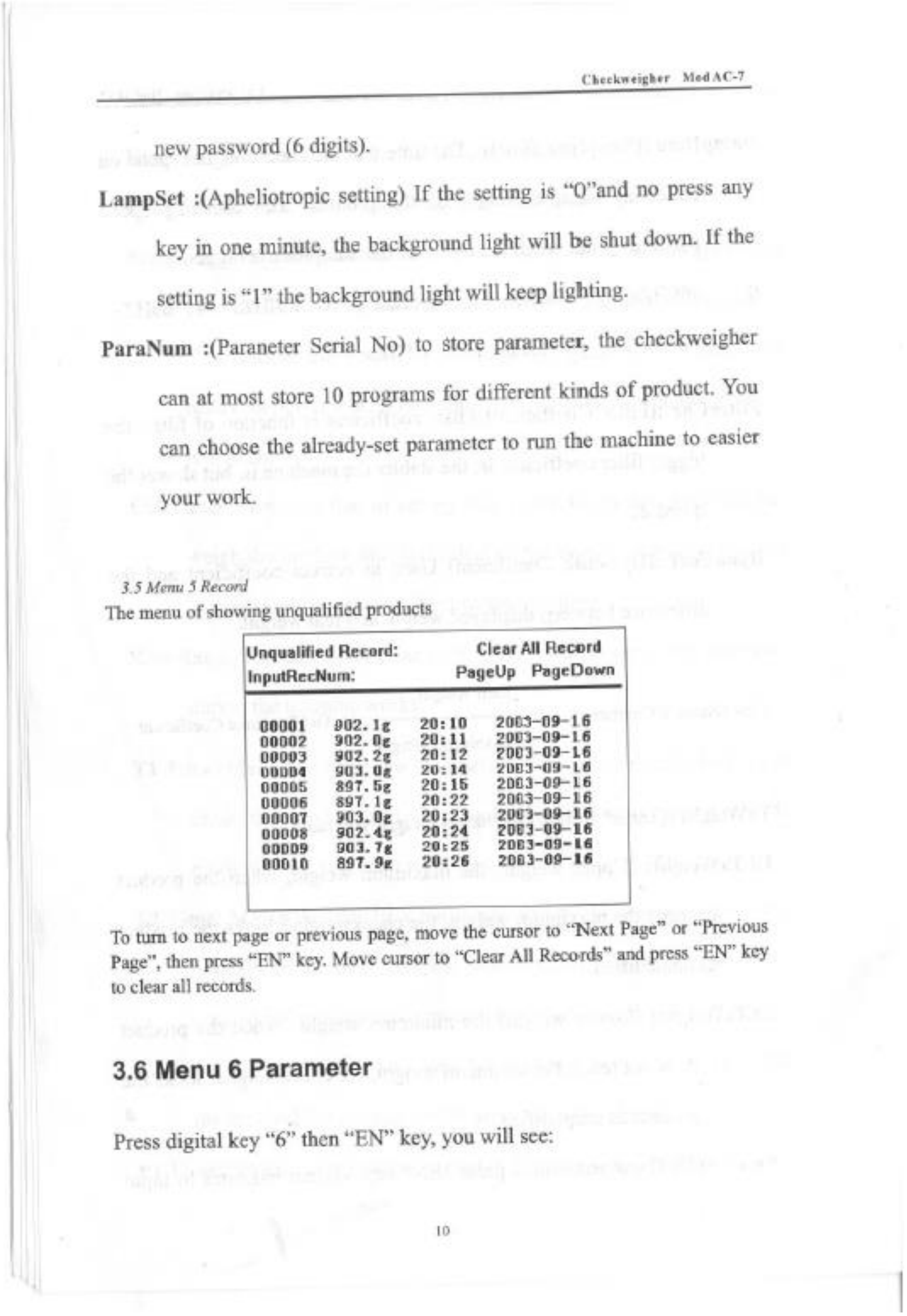
$$\text{New Dynamic Coefficient} = \frac{\text{Real Weight}}{\text{Displayed Weight}} \times \text{Old Dynamic Coefficient}$$

TaWeight :(Target weight) the target weight you need.

ULTaWeight: (Upper weight) the maximum weight, when the product exceeds the maximum weight, the checkweigher looks the product as unqualified.

LLTaWeight: (Lower weight) the minimum weight. When the product does not reach the minimum weight, the checkweigher looks the product as unqualified.

New PWD: (New password) press “EN” key, system indicates to input



new password (6 digits).

LampSet :(Apheliotropic setting) If the setting is "0"and no press any key in one minute, the background light will be shut down. If the setting is "1" the background light will keep lighting.

ParaNum :(Paraneter Serial No) to store parameter, the checkweigher can at most store 10 programs for different kinds of product. You can choose the already-set parameter to run the machine to easier your work.

3.5 Menu 5 Record

The menu of showing unqualified products

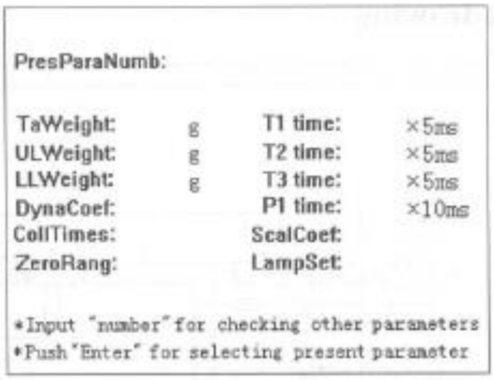
```
Unqualified Record:           Clear All Record
InputRecNum:                PageUp   PageDown

  00001    902.1g    20:10    2003-09-16
  00002    902.0g    20:11    2003-09-16
  00003    902.2g    20:12    2003-09-16
  00004    903.0g    20:14    2003-09-16
  00005    897.5g    20:15    2003-09-16
  00006    897.1g    20:22    2003-09-16
  00007    903.0g    20:23    2003-09-16
  00008    902.4g    20:24    2003-09-16
  00009    903.7g    20:25    2003-09-16
  00010    897.9g    20:26    2003-09-16
```

To turn to next page or previous page, move the cursor to "Next Page" or "Previous Page", then press "EN" key. Move cursor to "Clear All Records" and press "EN" key to clear all records.

3.6 Menu 6 Parameter

Press digital key "6" then "EN" key, you will see:



```
PresParaNumb:

TaWeight:      g     T1 time:    ×5ms
ULWeight:      g     T2 time:    ×5ms
LLWeight:      g     T3 time:    ×5ms
DynaCoef:            P1 time:    ×10ms
CollTimes:          ScalCoef:
ZeroRang:           LampSet:

*Input "number" for checking other parameters
*Push "Enter" for selecting present parameter
```

Select one program (0-9) in which already pre-set-up the parameter, and the checkweigher will run according to the parameters of the program.

T1 Time: Means after photoelectric sensor finishing product checking, it prolongs for T1 time to beginning collecting.
T2 Time: Means after check instrument finishing weight chick, it prolongs for T2 time ,then the air valve begins to work.
T3 Time: Means after photoelectric sensor finishing product checking, it prolongs for T3 time to set zero.
P1 Time: P1 time is the time the air valve runs, then stops.

4. Electrical drawing