UNIVERSITI PUTRA MALAYSIA

DESIGN OF A SMALL SCALE FACTORY FOR YAM BEAN SNACK (SENGKUANG CALIT)

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DESIGN OF A SMALL SCALE FACTORY FOR YAM BEAN SNACK (*SENGKUANG CALIT*)

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A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF BACHELOR OF ENGINEERING (PROCESS AND FOOD)

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ABSTRACT

Food factory is a manufacturing system that transforms raw ingredients into food product that can be consumed or easily prepared by the consumers using physical, mechanical chemical and thermal changes. In Malaysia, the food and beverage manufacturing are dominated by more than 95% of small and medium enterprises (SMEs). However, most SMEs have problems related to low productivity and hygiene. Previous studies showed that the problems can be sourced back to the poor design of the food factory that overlook aspects related to production efficiency and hygienic design. Thus, this project was performed to solve the productivity and hygiene requirement through the design of the new factory owned by Company X, a Malaysian SME that ventures in yam bean snack business in which the product consists of slice yam bean, sauces and roasted nuts. The new factory was designed using nine design stages that integrates the Good Manufacturing Practice (GMP) aspects and considers the productivity requirement. The new factory has a Production Program of 42560 kg/year, reserve capacity of 20%, Modified Atmosphere Packaging (MAP) processes, optimizes machines' capacity as well as has efficient spine layout, adequate number of facilities and utilities supplies. Simulation analysis with FlexSim software showed that the productivity of the new factory was increased by 2 times for all products, while the production lead time was reduced by 17% for slice yam bean, 90% for sauces and 67% for roasted nuts. The improvement was due the designated continuous line, tangible Production Program, optimized machines capacity and layout arrangement. Meanwhile, the analysis with Hygienic Checklist Tool shows that the new design complied with majorities of hygiene requirement (96%) thus, ready for implementing GMP once the operation is run. This include separation of low and high risk area, onward material and personnel flow, hygienic airflow, adequate spatial design and

building structures specification. In conclusion, an efficient and hygienic food factory system can be achieved when the productivity and GMP requirement were addressed as early as at the design process.

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ABSTRAK

Kilang makanan adalah sistem pembuatan yang mengubah bahan mentah menjadi produk makanan yang boleh dimakan atau mudah disediakan oleh pengguna yang menggunakan perubahan fizikal, mekanikal dan termal. Di Malaysia, pembuatan makanan dan minuman didominasi oleh lebih daripada 95% perusahaan kecil dan sederhana (PKS). Walau bagaimanapun, kebanyakan PKS mempunyai masalah yang berkaitan dengan produktiviti dan kebersihan yang rendah. Kajian terdahulu menunjukkan bahawa masalah boleh berpunca daripada reka bentuk kilang makanan miskin yang mengabaikan aspek yang berkaitan dengan kecekapan pengeluaran dan reka bentuk kebersihan. Oleh itu, projek ini dilaksanakan untuk menyelesaikan keperluan produktiviti dan kebersihan melalui reka bentuk kilang baru yang dimiliki oleh Syarikat X, sebuah SME Malaysia yang meneroka perniagaan snek 'Sengkuang Calit' yang produknya terdiri daripada sengkuang potong, sos dan kacang panggang. Kilang baru ini direka menggunakan 9 peringkat reka bentuk yang mengintegrasikan aspek Amalan Pembuatan Baik (GMP) dan mempertimbangkan keperluan produktiviti. Kilang baru ini mempunyai Program Pengeluaran sebanyak 42560 kg / tahun, kapasiti rizab sebanyak 20%, Proses Pengubahsuaian Kapasiti Modifikasi (MAP), mengoptimumkan kapasiti mesin serta susun atur tulang belakang yang cekap, jumlah kemudahan dan bekalan utiliti yang mencukupi. Analisis simulasi dengan perisian FlexSim menunjukkan bahawa produktiviti kilang baru meningkat sebanyak 2 kali untuk semua produk, sementara masa pengeluaran dikurangkan sebanyak 17% untuk sengkuang potong, 90% untuk sos dan 67% untuk kacang panggang. Peningkatan ini disebabkan oleh system pengeluaran berterusan yang ditetapkan, Program Pengeluaran yang jelas, mengoptimumkan kapasiti mesin dan pengaturan susun atur. Sementara itu, analisis dengan Alat Semak Kebersihan menunjukkan

bahawa reka bentuk baru memenuhi keperluan kebersihan yang besar (96%) dengan itu, bersedia untuk melaksanakan GMP sebaik sahaja operasi dijalankan. Ini termasuk pemisahan kawasan risiko rendah dan tinggi, aliran bahan dan kakitangan yang berterusan, aliran udara yang bersih, reka bentuk ruang yang mencukupi dan spesifikasi struktur bangunan. Sebagai kesimpulan, sistem kilang makanan yang cekap dan bersih boleh dicapai apabila keperluan produktiviti dan GMP ditangani seawal proses reka bentuk.

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CHAPTER 1

INTRODUCTION

1.1 Overview

The Malaysian food industry is dominated by small and medium scale companies and hence, act as the backbone of the nation's economy. According to Economic Census 2016 (2018), Malaysian SMEs (Small Medium Enterprises) now represent 98.5% (907,065 establishments) of the total establishments of 920,624 in the country (SME Corp, 2016). SMEs are categorized into many sectors such as services, manufacturing, agriculture, construction, mining and quarrying. SMEs also one of the major sectors in Malaysia that contributed around 36.65 % to Gross Domestic Product (GDP) and 18.6 % to exports in year 2015. In addition, the SMEs also offered 65.3 % employment opportunities in the year 2016 (SME Corp, 2016).

The Malaysian SMEs operate in three main economic sectors, namely manufacturing, services and agriculture (Nor et al., 2017). One of the sector that has been dominated by SMEs is the food and beverage manufacturing, whereby more than 95% of the companies are SMEs (MIDA, 2018). Realizing their significant role in the economic development of the country, food manufacturing sector have to be competent enough so that they continue to become important contributor to the Malaysian economic development and also, maintain their growth and survival in challenging market trade. Hence, several policies and programs have been initiated by the government in the past years to help food SMEs to grow such as SME Mentoring Programme for Halal Food

and Beverages (F&B) industry, Program Latihan Kemahiran Makanan Industri Kecil Dan Sederhana B40 (PLKB40) and Exporters Development Programmes (EDP) for food SMEs (Career Centre, 2017; NST, 2018; SME Corp, 2019).

Despite SMEs being a large part of mainstream businesses in food manufacturing sector and given numerous support programs, SMEs continue to face various challenges to compete in the global arena and survive in food industry. Aside from having financial and organizational problems, their manufacturing has not been able to supply timely demanded product as per market's requirement due to low productivity at their factory (Hasnan et al., 2014; Nor et al., 2017). They are also not able to tap the premium market due to incompliance to food hygiene standards, which eventually affect the quality of their food products and consequently affect their competitiveness and survival rate in the food industry (Musa and Chinniah, 2016). According to Jali (2016) and Hasnan et al. (2014), one of the reason for low productivity and incompliance to food safety standard is the poor design of the food factory itself that results in a problematic operation once the factory is operated. Therefore, this project is carried out to demonstrate the importance of design that considers productivity and food hygiene for establishing a competent food factory. The project is applied to a small-scaled manufacturing of ready-to-serve yam bean snack or popularly known as *Sengkuang Calit*.

1.2 Problem Statement

Company X is a local enterprise that has been venturing in franchising business for yam bean snack since 2012. The snack or known as 'Sengkuang Calit' is produced in a small kitchen through manual processes and based on a family recipe. The premise is located at Jalan Gurney, Kuala Lumpur. Company X has about 63 franchisees around Malaysia such as in Kelantan, Pahang and Selangor. The prepared components

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of yam bean snack are been supplied in bulk to the franchisees, whereby the franchisees would then prepared the snack according to the Standard Operation Procedure (SOP) and serve to customers at their own premise. The yam bean snack consists of sliced yam bean (fresh-cut), red sauce, soy-based sauce and roasted nut.

At present, the company is running a production with low productivity. Although the demand of the products can reach up to 2000 kg per month, yet, the current production could only cater for 1000 kg per month, which is about 50 % from the real demand. Most of the times, the company has to refuse customers' order due to the difficulties to deliver the products according to the order deadline. The problem is informed to occur due to too many manuals, incorrect process steps, insufficient production capacity (machine and man-power) and congested layout.

Another problem faced by the company is the difficulties to practice hygiene and food safety in the production, which affect the quality and shelf life of fresh-cut yam bean. It is reported that the delivered yam bean can sometimes spoil rapidly at franchisees within 2 days although put in cold condition. The products are seen with yeast and mold most probably absent due to lack of hygiene such as improper process segregation, inadequate processing controls, no barrier and absent of personal hygiene facilities.

Due to the need to increase their production output, products quality and hygiene, Company X has decided to set-up an efficient factory system and pursue a proper hygienic premise. The design of the new factory system should therefore consider the production demand as well as the food hygiene requirement. This effort has seen as necessary to increase the competitiveness of the company in food industry.

1.3 Goal and Objectives

The main goal of the project is to deliver a competitive factory design for the new production of yam bean snack. The specific objectives of the project are as follows:

1) To design an efficient and hygienic food factory system for the small-scale production of ready-to-eat (RTE) yam bean snack.

2) To analyze the productivity improvement in the new factory compared to the existing snack production using simulation analysis (Flexsim Express)

3) To evaluate Good Manufacturing Practice (GMP) elements in the design of the new snack factory using Hygienic Design Checklist Tool software.

1.4 Significance of Work

Upon completing this project work, a factory design and specification for the yam bean snack is proposed. The design should be able to deliver a factory system that is production efficient and able to implement hygiene. In order to achieve this, a suitable manufacturing system and layout are presented, productivity improvement in new factory is compared to existing production and the hygienic design are evaluated. The outcome of this project shall prepare the factory certified with GMP which is important for meeting global food safety and quality standard.

In a bigger perspective, the study shall demonstrates the feasibility and method to set-up a competent food factory for the SME industries. This study is therefore in line with the current Eleventh Malaysia Plan, 2016-2020 and SME Masterplan 2012-202 that has their focus on boosting the productivity of SMEs and compliance to global food standard (SMECORP, 2018).

1.5 Structure of Thesis

This thesis comprises of five chapters.

Chapter 1 is the introduction for this study which presents an overall idea in this study.

Chapter 2 is the literature review for this study which reviews the existing knowledge that will be the input information for this study.

Chapter 3 is the methodology that describes the detailed work flow and procedures to perform this study.

Chapter 4 is the result and discussion that presents result in related to the factory design and specification as well as analysis conducted.

Chapter 5 is the summary for this study which include the conclusion, project challenges and recommendation for future work.

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CHAPTER 2

LITERATURE REVIEW

This chapter gives an overview on the prior studies related to food factory design and problems related to efficiency and hygiene. The potential of convenience food in food processing sector is also included in this chapter. The chapter also reviews on the issues and challenges to design a competent food factory and available design analysis method.

2.1 Potential of Convenience Food and Vegetable Snack

Convenience food can be defined as category of foods that need least handling such as gentle heating, ready-to-eat products or rehydration in hot or cold water for dried out foods (Saxena, 2017). In other words, convenience food does not require major cooking or processing by the consumers before they can consume the food. However, convenience food has their own complexity which relies on their composition, perishability and method of handling (Manzini and Accorsi, 2012). In addition, the prime concern that need to be focused are the long shelf life, good quality and the commercial availability of the convenience food (Arya, 1992).

According to Convenience and Health Food (2012), convenience food can be classified into 3 groups which are ready to eat foods (RTE), ready to use foods (RTU) and beverages. Vegetable snack which is yam bean snack is classified as ready to eat food (RTE) as the food can be directly consumed from the package by warming, thawing or minor preparation.

Based on The Nielsen Global Survey of Snacking (2014), vegetable snack has high potential to become the commercialized snack due to increase in consumption and preference around the world. The statistic by the Nielsen Global Survey of Snacking (2014) shows that aside from fresh fruit and chocolate, large percentages of respondents also prefer snack on vegetables in Asia-Pacific (57%). Large percentage on snacking of vegetables in Asia-Pacific shows a positive trend of vegetable snack and thus give the opportunity for this market to grow well. Furthermore, consumers are now also demanding foods in the form of easy-to-prepare, ready-to-cook, and ready-to-eat due to the change in lifestyle (Ismail & Yusop, 2014).

In Malaysia, one of the classic vegetable snack that has become increasingly popular in the cities the yam bean snack or *Sengkuang Calit* (Shawal, 2014) as mentioned in the news in Figure 2:1. The snack is made of a slice of fresh yam bean, served with soy- and red sauce and topped with grinded peanuts. It's fresh and chill taste as well as crunchy texture makes it suitable as entree or dessert (Shawal, 2014). At present, the yam bean snack has moved from individual selling at stall or night markets to a wholesale business, whereby a particular franchiser is producing the snack in batches and supplies them to their franchisee. The commercialization is pursue by young entrepreneurs classified as micro and small enterprises (Hat, 2014). The production is done in a small premise, whereby the components of the snacks are usually supplied separately to the franchisee and the franchisee has to prepare them at their own premise before serving (Shawal, 2014).

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Figure 2.1. News on yam bean snack or Sengkuang Calit (Source: Shawal (2014) and Hat (2014))

2.2 SME Operational Issues Due to Incompetent Design

Two major issues are constantly found in reports and literature related to Malaysian Small and Medium Enterprises (SMEs) which are low productivity and hygiene issue. The following review has identified that the rise of the mentioned issues is in some ways are related to poor factory system design. These are discussed in the next sections.

2.2.1 Low Productivity Issue

According to Economic Census 2016 (2017), SMEs now represent 98.5% (907,065 establishments) of the total establishments of 920,624 in the country (SME Corp, 2016). Meanwhile, the Malaysian food processing is dominated by SMEs as

they are already reaching to more than 96 % of establishment in the sector (DOSM, 2011). However, despite their majority in the sector, the latest statistic by the Department of Statistics Malaysia (DOSM) has shown their low productivity, causing the increasing in food import bill for the processed food (DOSM, 2015). In addition, the production index also shows a negative value due to low productivity of the company and has impacted the total growth of food industry in Malaysia.

Based on Amit et al. (2012), the low productivity can be sourced back to overlook in the planning of factory such as insufficient capacity, inappropriate layout, material handling and overlook on production volume requirement. Rani et al. (2014) has further reported inefficient allocation of the operators in the food factory may also affect the production operation. Saudah et al. (2015) and Ojagi et al. (2015) had reported the inefficiencies in production flow may arise due to poor layout in the small scale food processing. Bottleneck problem may also arise due to poor capacity planning (Amit et al., 2012). The design problems then lead to the long manufacturing lead time and thus, results in low productivity (Hasnan et al., 2014; Saudah et al., 2015).

2.2.2 Hygienic Issue

Good Manufacturing Practice (GMP) and Hazard Analysis and Critical Control Point (HACCP) are important food safety management system as customer can be safely assured that the production has been carried out in a safe manner. Importantly this certification not only ensure the consumer confidence on the products but also assist industry in expanding their market to international level (FSQD, 2015). In Malaysia, the certification of GMP and HACCP is governed by Ministry of Health Malaysia (MOH):

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1) Malaysian Standard (MS) 1514: 2009 Good Manufacturing Practice (GMP)
2) Malaysian Standard (MS) 14: 2009 Hazard Analysis and Critical Control Point (HACCP)

HACCP system focuses in assuring safe production of food products during preparation, processing, manufacturing, packaging, storage, transportation, distribution, handling or offering for sale or supply in any sector of the food chain (SIRIM, 2007). Meanwhile, GMP is a prerequisite and has to be in-place first before a premise can successfully implement HACCP system. The specific guideline for the hygienic design is outlined in MS 1514 GMP is detailed out in Section 2.5. At present, there are still low numbers of food factories in Malaysia had been certified with GMP. As of December 2015, a total of 243 companies have received GMP certification which is less than 4% of the total food processing companies in Malaysia (FSQD, 2015). In addition, SMEs are reported to have confusion and misunderstanding in implementing the GMP requirement for hygienic design due to lack of technical clarity (Jali et al., 2016).

There have been recurring closures of local food premises due to the filthy condition. This condition can be sourced back to the poor hygienic design of a food factory. There were factories that are severely infiltrated with pest. Apart from that, by not providing a sufficient hand wash and change room is also a criteria of poor hygienic design of food factory (Jali et al., 2016). This condition will cause the workers in the food factory to have a poor personal hygiene and allow the easy transmission of pathogen as well as yeast and mold from surrounding to the food.

In addition, the poor layout design is also one of the criteria that will affect the hygienic condition of a food factory (Van Dock, 2004). This is due to the wrong layout design

that will results in cross contamination to the food and affect the microbiological food safety. Malaysian Association of Standard Users (2015) has also reported the metal detector is not planned to be integrated in the production line leading to findings of metals in the end-product from the local food brands. According to Jali et al. (2016), poor sanitary design will provide unhygienic environment of a food factory. This unhygienic condition will cause the food quality to deteriorate quickly.

2.3 SME Challenges to Design Food Factory

Based on Manzini (2012), processing of food is complex and need to concern on the quality, safety, sustainability and logistics efficiency of food product along the whole food supply chain (FSC). In other words, food are perishable item and has sensitive components that need to be handled properly. They are in bulk material and need to be turned into single item food products by following certain procedures that involve change in thermal, chemical, physical, rheological and mechanical properties. Thus, the manufacturing of each food factory is unique depending on the raw materials, required end product, shelf-life, seasonality, processes and technologies applied. This uniqueness reflects the complexity in designing a well-functioning food factory and thus, a challenge for SMEs that have many constraints as described in the next following sub-sections.

2.3.1 Lack of Finance

Alam (2010) has quoted in his survey that lack of financial resources is the main barriers for SMEs growth. His study found that financial barriers have the most significant impact on the growth of food processing SMEs. Another similar result was obtained by a survey conducted by Zain et al. (2012), in which respondents from SMEs in food industry have ranked financial issues as the most significant challenge.

2.3.2 Lack of Knowledge

According to Talib et al. (2013), SMEs are business entities that experience problems in expending and succeeding due to the lack of knowledge and eventually the actual know-how. One of the reason is that most SMEs (especially micro and small enterprises) are family businesses and a technical expertise is often 'passed down', which may lag behind modern technology and may not be the most innovative for the company's good (The Business Times, 2014). Such 'training' is not organized and gives no continuity (The Business Times, 2014).

2.3.3 Informal and Unsystematic Design Method

SMEs are usually very limited in their skills because the cost to hire professional and efficient workers are very high (Rani et al., 2014). So, they are unable to hire consultant and decide to use simple informal approach and trial-and-error in planning and designing their factory. As a result, by using this informal and unsystematic method, they fail to manage the factory system as too many production issues arise comes time to time. They also cannot cater the productivity required and provide unhygienic surrounding during the operation (Ojaghi et al., 2015, Jali et al., 2016).

2.4 Design of Hygienic Food Factory

According to Food Hygiene Regulations 2009 or Peraturan-Peraturan Kebersihan Makanan (PPKM 2009), a food premise must be designed to be hygienic and easy-to-clean as well as easy to maintain. However, the regulations has only enforced the law and does not outline the guideline for the hygienic design in details. The Malaysian Standard (MS) 1514 Good Manufacturing Practice for Food was first distributed in 2009 to guide the local industries in designing a hygienic food factory by detailing the requirement for the hygienic design in Section 4 of the standard (SIRIM, 2009). The

main objectives of hygienic design are to ensure that location, design and construction of food premises, equipment and facilities are capable to achieve (SIRIM, 2009):-

- Minimization in contamination;
- Design and layout allow appropriate maintenance, cleaning and disinfection and minimize air-borne contamination;
- Surfaces and materials, especially food contact surfaces are toxic free in intended use, suitably durable and easy to maintain and clean;
- Suitable facilities are available for temperature, humidity and other control;
- Provide effective protection against pest access and harbourage.

The summary of the standard requirement for the GMP Hygienic Design based on MS 1514 is is given in Table 2.1. As can be seen in Table 2.1, GMP Standards only specify hygienic design requirement in details compared to Food Hygiene Regulation 2009, but does not explain on how to technically achieve the requirements. This is a challenge for SMEs as they are lack of knowledge and know-how which then lead to confusion and eventually unstandardized implementation of the design at their premise (Jali et al., 2016).

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Table 2.1. Summary of GMP Design

Design Elements	Summary
Location	In particular, the establishment should be located away from areas subject to flooding , area prone to pest infestations, areas where wastes, either solid or liquid, cannot be removed effectively and areas which are environmentally polluted with industrial activities that can pose potential and serious threat of contaminating food.
Premises and room	1) Layout : Should permit good food hygiene practices, including protection of foodstuffs against cross-contamination during and in between operations. 2) Internal structure and fitting : Should be soundly built of durable materials and be easy to maintain, clean and where appropriate, able to be disinfected.
Equipment	1) General design: Should be made of materials with no toxic effect in intended use. Where necessary, equipment should be durable and moveable of being disassembled to allow for maintenance, cleaning, sanitisation and to facilitate inspection for pests. 2) Design of control and monitoring equipment: Equipment used to cook, heat treat, cool , store or freeze food should be designed to achieve the required food temperatures as rapidly as necessary in the interests of food safety and suitability and maintain them effectively.

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Table 2.1 continued.

Facilities	1) Water supply: An adequate supply of potable water with appropriate facilities for its storage, distribution and temperature control, shall be available to ensure the safety and suitability of food. 2) Drainage and waste disposal: Drainage channels are fully or partially open, they are to be so designed as to ensure that waste does not flow from a contaminated area towards or into a clean area, in particular an area where foods likely to present a high risk to the final consumer, are handled. Cleaning facilities: Adequate facilities, suitably designated , shall be provided for cleaning food, utensils and equipment. 3) Personal hygiene facilities: Include adequate means of hygienically washing and drying hands (wash basin and sanitizers), adequate number of toilets and not to open directly into rooms where food is handled and adequate changing facilities for personnel . 4) Temperature control: Depending on the nature of the food operations undertaken, suitable facilities of sufficient capacity should be available to ensure safety and suitability of food. 5) Ventilation system: Should be designed and constructed so that air does not flow from contaminated areas to clean areas and can be adequately maintained and cleaned. 6) Lighting: Adequate natural or artificial lighting should be provided to enable the undertaking to operate in a hygienic manner. 7) Storage: Adequate facilities for the storage of food, ingredients and non-food chemicals such as cleaning materials or lubricants should be provided.

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2.5 Integrated Design Method for Food Factory

There are many general design method that can be used to design food factory. The literatures are mostly aimed to provide comprehensive understanding on individual design of factory components and describe the variety design of factory approach. Holah (2011) has stated in his design regarding the solution on hygienic design for different parts of the factory. Meanwhile, the principles of food process with explanation on processing line, operating parameters, mass and energy balance, fluid properties and thermodynamic has been described by Saravacos and Kostaropoulos (2002) in their literature. Yet, a step-by-step procedure to design an entire specific factory from beginning is hardly found in the literatures. Thus, it is not well understood how every individual design fit in the overall design process and often, overlook the unique considerations for food processing SMEs.

Hasnan et al. (2018) has specifically covered the procedural form (stage by stage) to design the entire burger patties factory with explicit requirement on production efficiency and hygiene. The procedures also oriented the design according to the manufacturing system elements such as material, process, machine, facilities , logistic and operators.. The design starts with the production output and capacity planning in accordance to demand, process planning, machine capacity and selection, layout design, space and workforce allocation and building design. The advantages of the procedures is the simultaneous incorporation of hygienic and efficiency techniques in the design of food factory system. At the end of the design, a new food factory specification can be obtained with a defined Production Program, Process Specification and Flow Sheet, Machine List, Room Design Data Sheet, Space and

Workforce Program, Layout and Building Specification. The procedural flow is given in Figure 2.2 (Hasnan et al., 2018) which will be used in this final year project. The details of the design procedure is given in Chapter 3 Methodology.

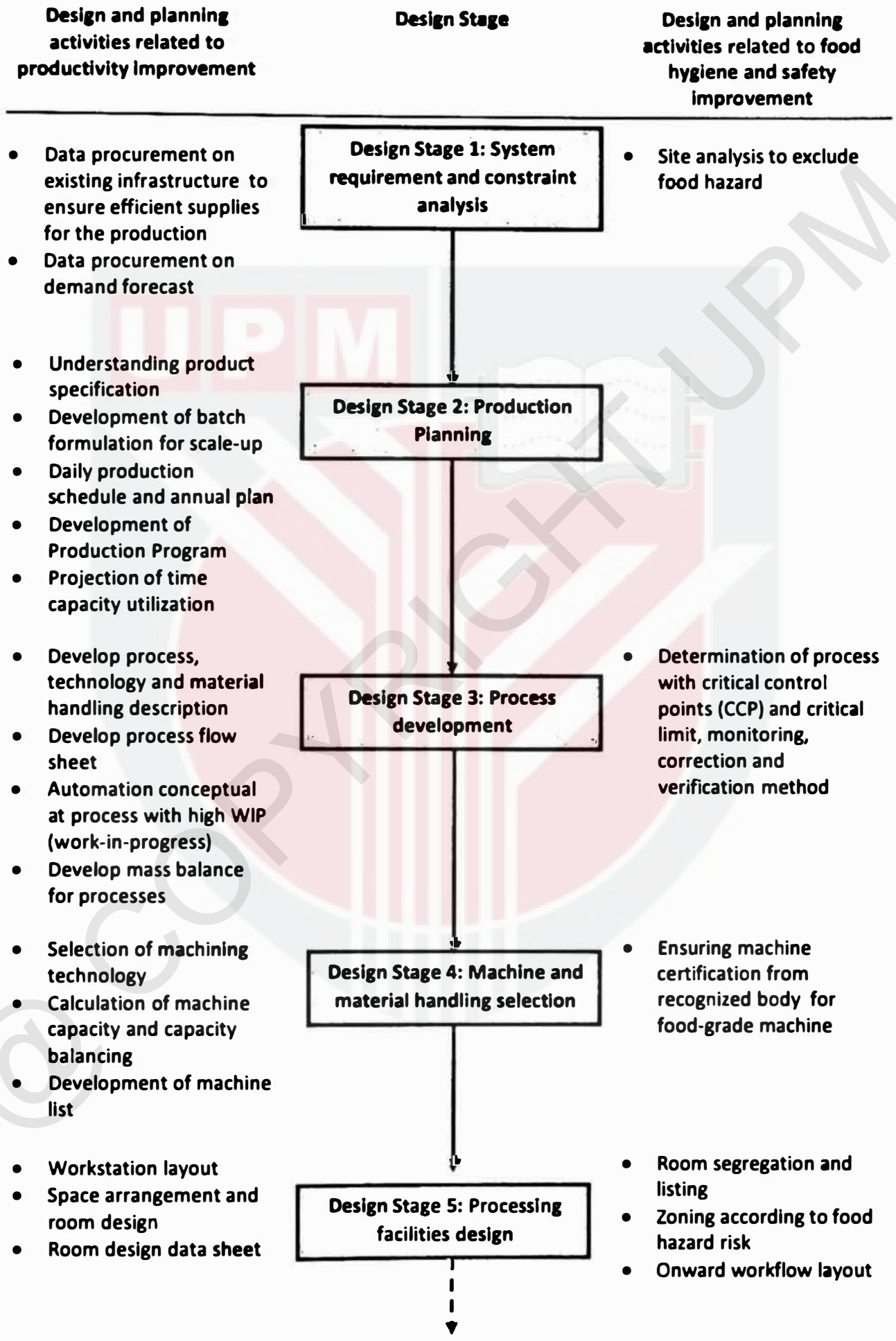


Figure 2.2. Design Procedures for Food Factory System (Hasnan et al., 2018)

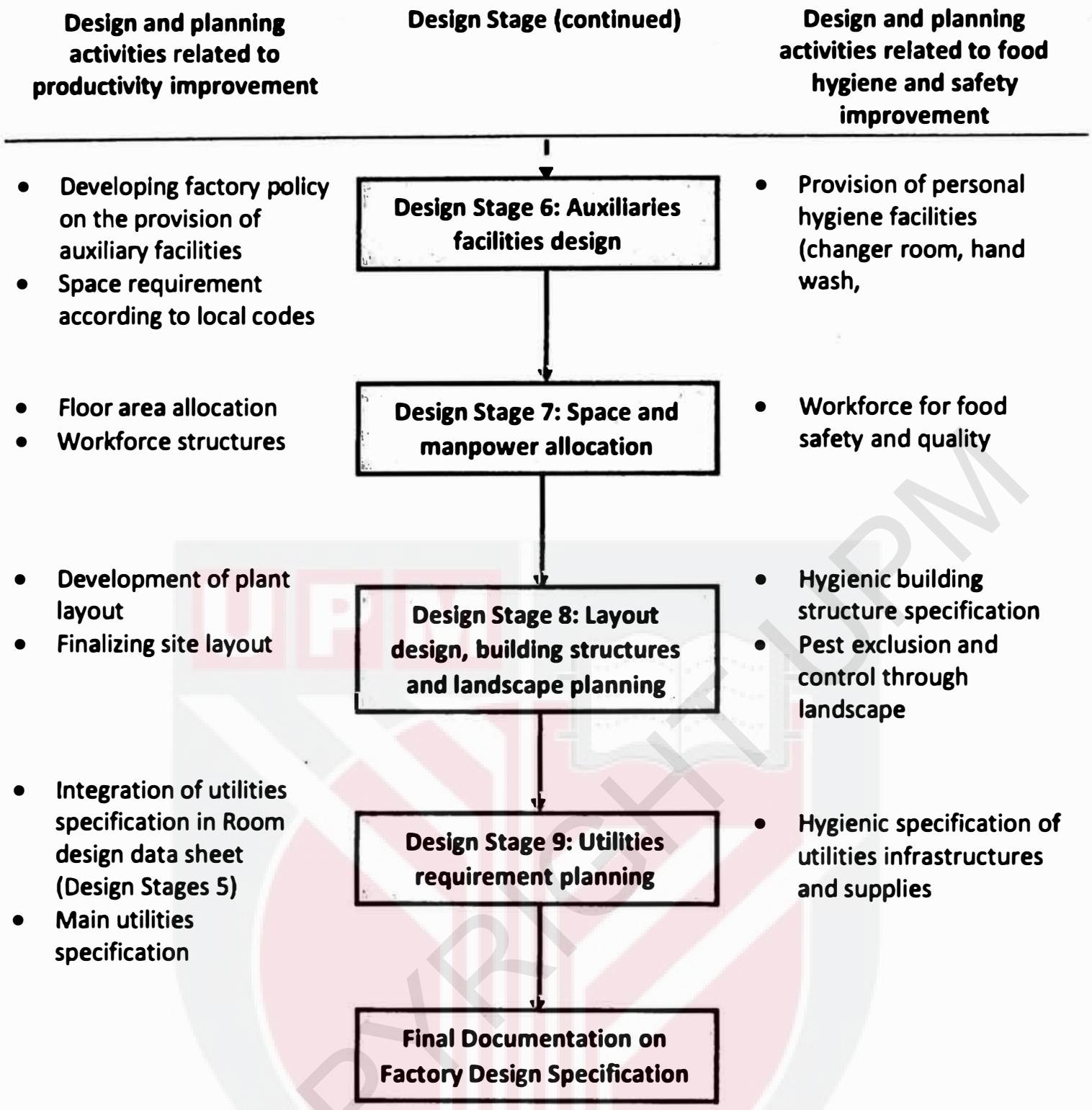


Figure 2.2 continued. Design Procedures for Food Factory System (Hasnan et al., 2018)

2.6 Design Analysis Method

This section presents the design analysis tools that were found to be useful for this study. It is important to carry out design analysis to evaluate whether the design developed in this study is able to achieve the required productivity and hygienic design.

2.6.1 Productivity Analysis using Simulation and Modelling Analysis

It has been proven that one of the most useful analysis tools in the manufacturing system design areas is the simulation software (Dwijayanti et al., 2010; Amit et al., 2012; Negahban and Smith; 2014; Rani et al., 2014). Simulation is defined as a broad collection of methods and applications to imitate the behaviour of real systems. Simulation software tools that are commonly used for design analysis are Arena, QUEST, IGRIP, ProModel and Witness (Dwijayanti et al., 2010; Rani et al., 2014a).

The use of simulation enables the designer to model the designated factory system as a virtual factory system, and then, visualize as well as gain understanding on the behaviour of the system when operating (Negahban and Smith, 2014; Amit et al., 2012). Users are able observe effects of changes in variables over weeks, months or years in a short time through simulation. In addition, the conduct of experiments can be repeated many times to get an accurate result, while the system environment can be controlled according to the user requirement (Altiok and Melamed, 2007).

The simulation would be highly preferable to validate the design concept and functionalities, since the cost to actually building the plant and testing the system can be expensive and required involvement from many parties. In case of improving the existing system, simulation enable the evaluation to be performed without physically affect or disturb the actual system (Rani et al., 2014a; Amit et al., 2012).

The use of simulation software was reported to be particularly useful when analysing productivity and production lead time in food processing (Rani et al., 2014). Hecker et al. (2010) used simulation models to investigate the effect of rescheduling the production planning on operators working time in a bakery factory. The study had resolved all bottlenecks, improved utilization of all machines, eliminated most of the

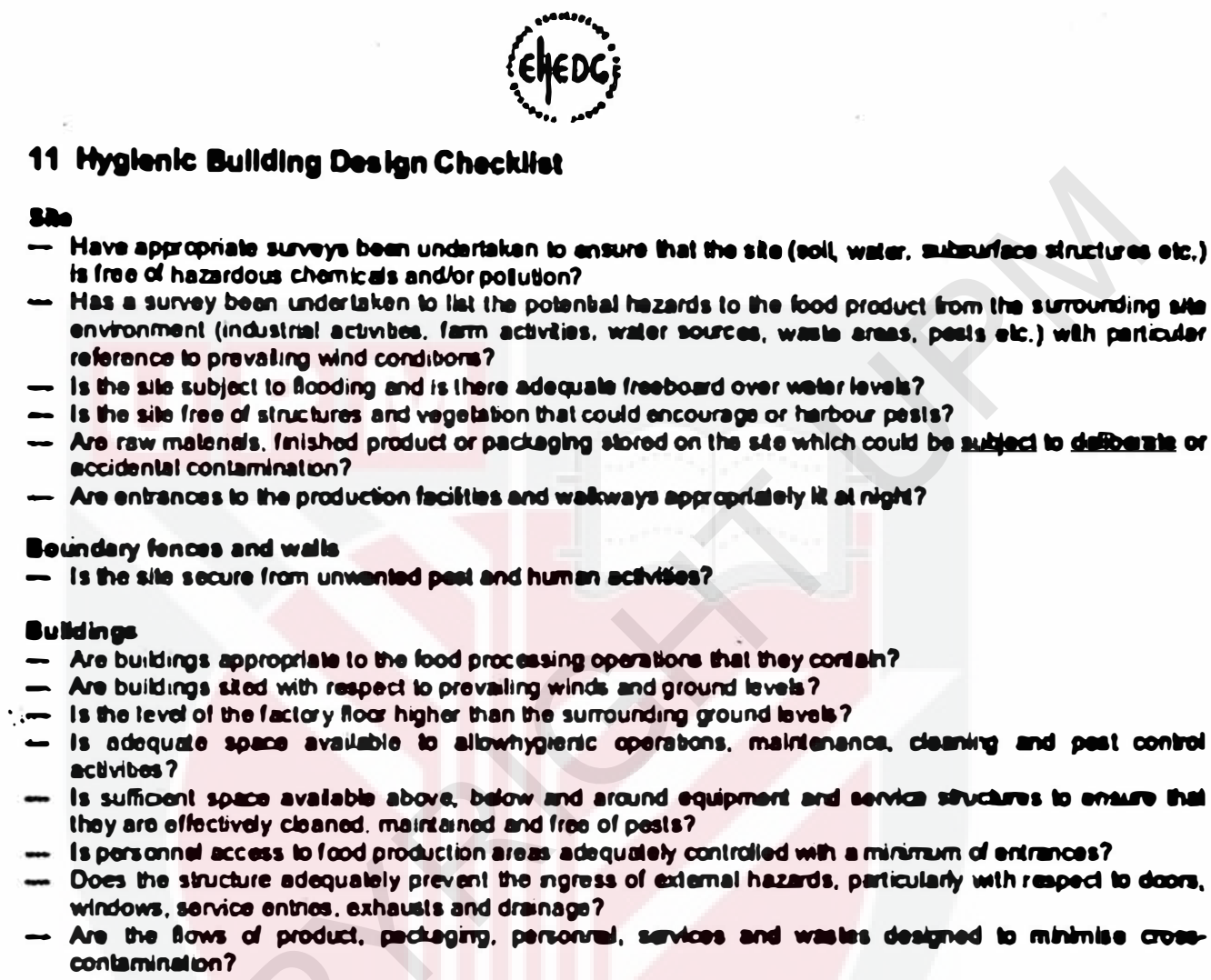
waiting time at many stations. Amit et al. (2012) had redesigned the layout of snack processing plant using systematic layout planning (SLP) approach. The proposed layout was evaluated using simulation Software and showed improvement in total travel distance, total travel time, total travel cost and output. The studies have shown that simulation is a suitable method to analyse problems faced by food manufacturers and improve the performance of the factory systems. Thus, the simulation analysis using FlexSim would be used in this study for investigating the success of the developed yam bean factory design in increasing productivity.

FlexSim is a powerful yet easy-to-use software for simulation. A comprehensive and innovative simulation engine is hidden behind drag and drop controls, drop-down lists and many other intuitive features that make it accessible for anyone to model the manufacturing system and analyse the change in model setting. All simulation model are created to a defined scale and are presented using 3D visuals, so it becomes easy to view and recognize bottlenecks in the production line or other deficiencies within the system. FlexSim also gives decision makers the tools to confirm their observations, with impressive statistical reporting and analysis built right into the software.

2.6.2 Hygienic Design Analysis

The hygienic design evaluation is carried out based on a review of technical drawings and design specifications before the actual building is constructed. The European Hygienic Engineering and Design Group (EHEDG) database has recommended the use of "Hygienic Design Checklist Tool", developed by the American Grocery Manufacturers Association (GMA), to quantitatively evaluate whether the designs complied with the hygienic design principles. Another useful hygienic design checklist has also been developed by EHEDG which is named as "Hygienic Building Design

Checklist" as in Figure 2.3 and is contained in DOC 44 Hygienic Design Principles for Food Factories. However the checklist only provide qualitative results compared to Hygienic Design Checklist Tool by GMA.



11 Hygienic Building Design Checklist

Site

- Have appropriate surveys been undertaken to ensure that the site (soil, water, subsurface structures etc.) is free of hazardous chemicals and/or pollution?
- Has a survey been undertaken to list the potential hazards to the food product from the surrounding site environment (industrial activities, farm activities, water sources, waste areas, pests etc.) with particular reference to prevailing wind conditions?
- Is the site subject to flooding and is there adequate freeboard over water levels?
- Is the site free of structures and vegetation that could encourage or harbour pests?
- Are raw materials, finished product or packaging stored on the site which could be subject to deliberate or accidental contamination?
- Are entrances to the production facilities and walkways appropriately lit at night?

Boundary fences and walls

- Is the site secure from unwanted pest and human activities?

Buildings

- Are buildings appropriate to the food processing operations that they contain?
- Are buildings sited with respect to prevailing winds and ground levels?
- Is the level of the factory floor higher than the surrounding ground levels?
- Is adequate space available to allowhygienic operations, maintenance, cleaning and pest control activities?
- Is sufficient space available above, below and around equipment and service structures to ensure that they are effectively cleaned, maintained and free of pests?
- Is personnel access to food production areas adequately controlled with a minimum of entrances?
- Does the structure adequately prevent the ingress of external hazards, particularly with respect to doors, windows, service entries, exhausts and drainage?
- Are the flows of product, packaging, personnel, services and wastes designed to minimise cross-contamination?

Figure 2.3. A partial view on Hygienic Building Design Checklist by EHEDG (2014)

In this study, the GMA Hygienic Design Checklist Tool is used to evaluate the drawing and designs specification of the yam bean snack factory. The GMA checklist tool is provided in the Appendix A. The use of GMA checklist provides an insight on GMP design achievability, since the GMA council consisted of a Standards Committee that examines the standard-setting bodies including Codex and ISO (GMA, 2016).

The checklist is divided into ten sections as shown in Table 2.2. Every section has several criteria to be evaluated and scored. The questions are answered by either "S" for satisfactory, "M" for design is marginally acceptable, "U" for unsatisfactory or

"NA" for requirements is not applicable in that design case. Points are automatically given by the tool based on the answers. A full score shows the hygienic design is satisfactory, while a score of less than 100% requires the design to be improved (Nikoleiski, 2012).

Table 2.2. Ten sections in GMA Facility Design Checklist

Section	Principles
1	Distinct Hygienic Zones Established In The Facility
2	Personnel and Material Flows are Controlled to Reduce Hazards
3	Water Accumulation Controlled Inside Facility
4	Room Air Flow and Room Air Quality Controls
5	Site Elements Facilitate Sanitary Conditions
6	Building Envelope Facilitates Sanitary Conditions
7	Interior Spatial Design Promotes Sanitation
8	Building Components and Construction Facilitate Sanitary Conditions
9	Utility Systems Designed To Prevent Contamination
10	Sanitation Integrated Into Facility Design

The total points for the checklist is 1000 corresponding to 106 criteria. If the evaluation scores is between 50 to 100%, a continuous improvement is required. The score below 50% shows the hygienic design is unsatisfactory and a redesign is required (Nikoleiski, 2012).

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CHAPTER 3

METHODOLOGY

This chapter presents the method used to achieve the objectives of this research project. Firstly, there will be an overview about the case study company. Next, the work flow of the project is presented. Every stage of the project will be explained on how it was performed.

3.1 Case Study Object

Prior the design stages, it was important to understand the company's profile and its current production. Therefore the information was procured by periodically discussion with the companies, site observation and document's revision. The following sections described the information on the company and its production.

3.1.1 Company's Profile and Product

Company X is a local enterprise that has been venturing in franchising business for yam bean snack since 2012. The snack or known as 'Sengkuang Calit' is produced in a small kitchen as shown in Figure 3.1 through manual processes and based on a family recipe. The premise is located at Jalan Gurney, Kuala Lumpur. Company X has about 63 franchisees around Malaysia such as in Kelantan, Pahang and Selangor. The prepared components of yam bean snack are supplied in bulk to the franchisees, whereby the franchisees would then prepared the snack according to the Standard Operation Procedure (SOP) and serve to customers at their own premise. The yam bean snack consists of sliced yam bean (fresh-cut), red sauce, soy-based sauce and roasted nut as shown in Figure 3.2.

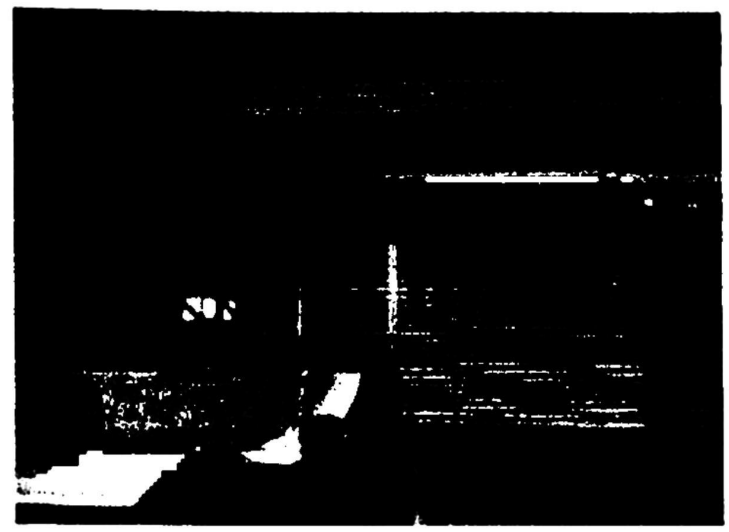

Figure 3.1. Company X's kitchen

Figure 3.2. Yam bean snack

3.2 The Overall Methodology

For the overall methodology of the project consists of four phases namely project initiation, design and engineering, project monitoring and closing of the project. The chart in Figure 6 showed the phases of the project starting from the first design phase until the last design phase.

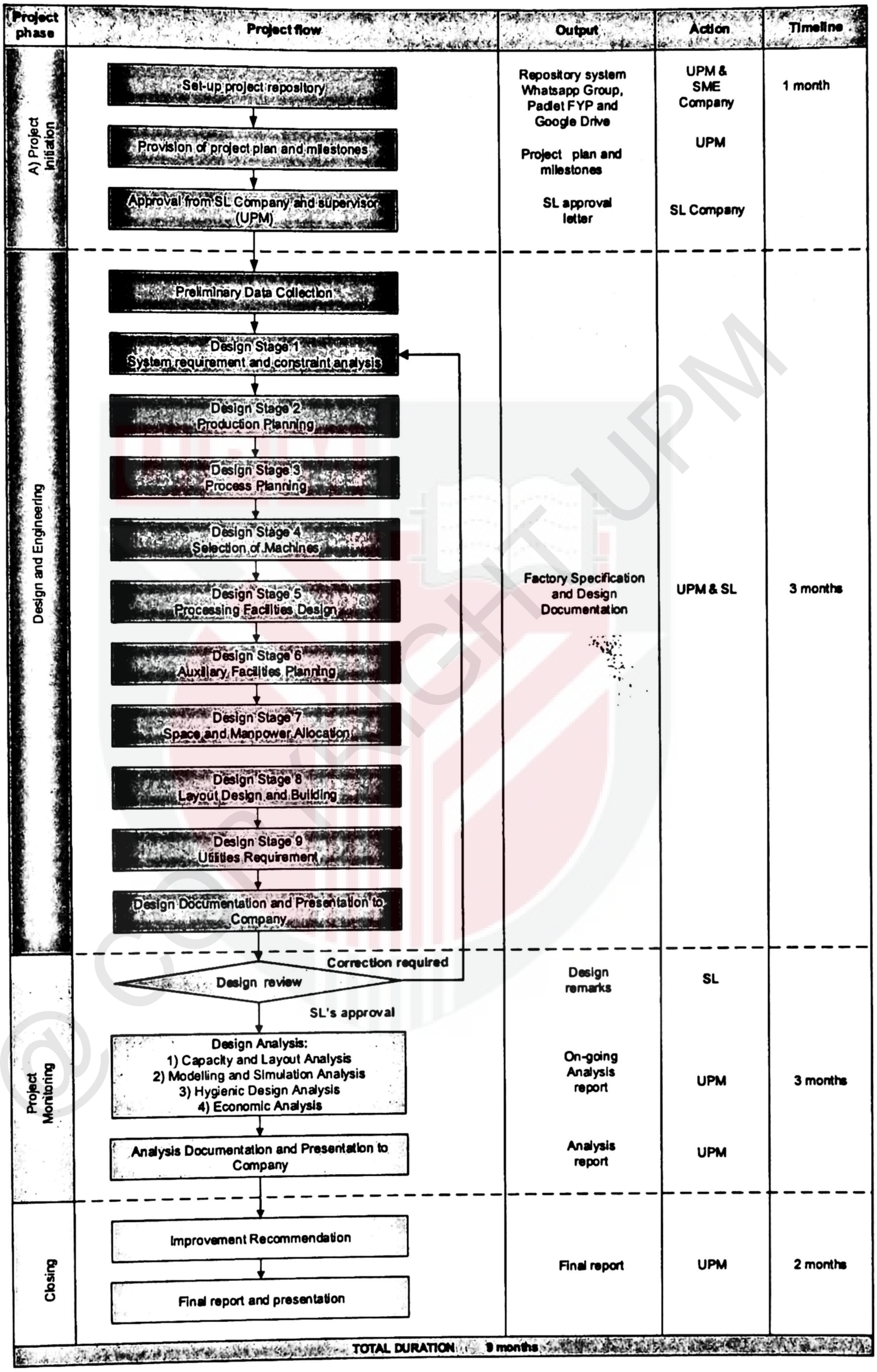

Figure 3.3. Overall methodology

3.3 Phase 1: Project Initiation

The project begins with setting up the project repository to allow communication between parties involved in the project. This include WhatsApp group, Google Drive and Padlet software that helps to store the journals and references. The project plan, proposal and schedule was developed and submitted to the department as well as the company X. Upon approval by the department and the industry, the project proceeded to Phase 2: Engineering and Design.

3.4 Phase 2: Engineering and Design

Before proceeding with the design activities, the data were collected based on meeting with the company representatives to analyse the current prodctuivity and hygieng or food safety problems. The potential location of the New Factory X in Pusat Perindustrian Sungai Chua, Kajang was also visited on 15th February 2019 and located in Figure 3.4. The New Factory X is to be accommodated in a terrace factory which have a 9 m x 30 m x 3 m measurement on the ground floor.

Figure 3.4. Location of New Factory X

This project applies nine design stages as shown in Figure 3.5 for the factory system of yam bean (Hasnan et al., 2017). The execution of the design stages are described in Section 3.4.1 to 3.4.9.

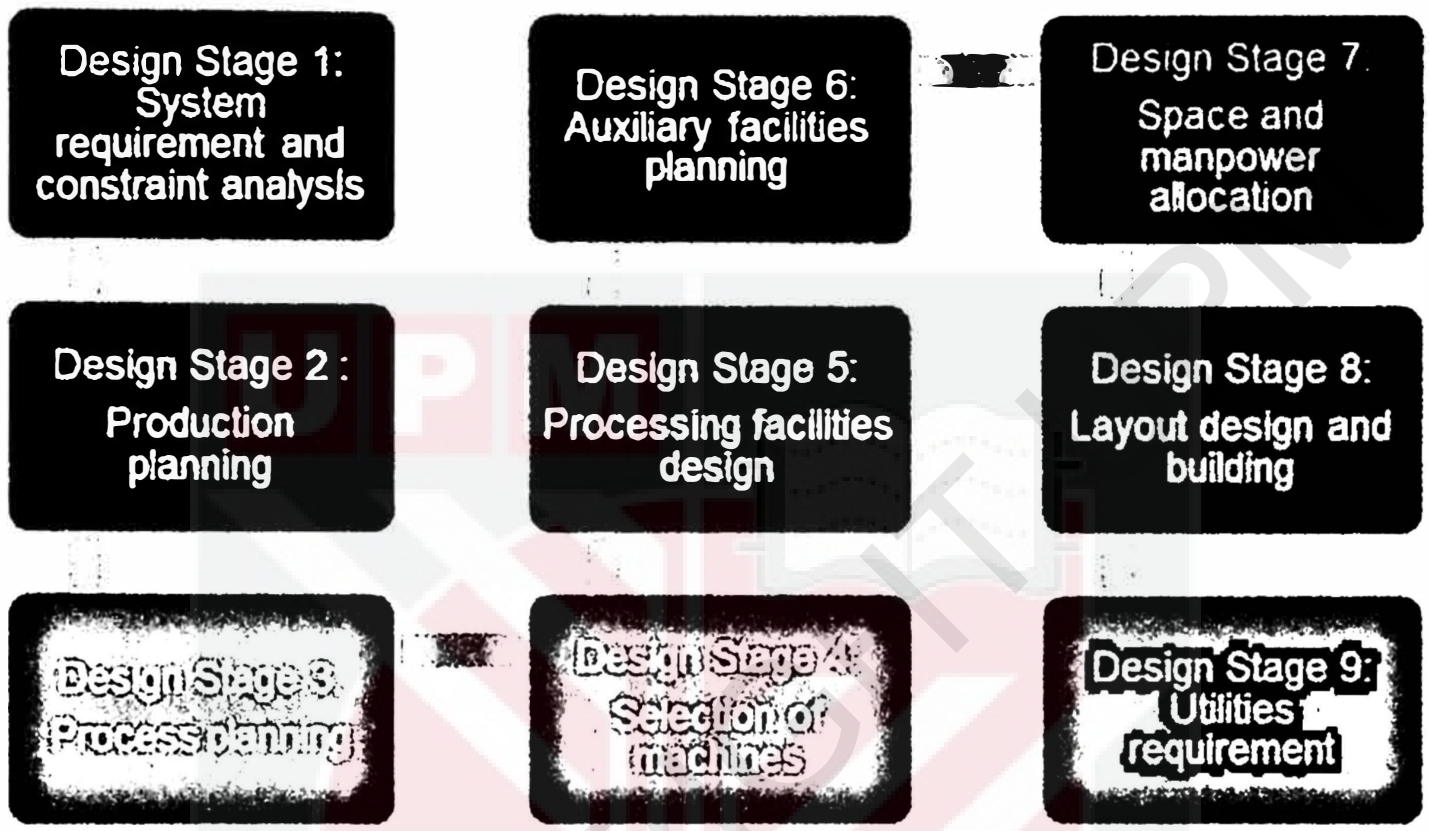

Figure 3.5. Nine Stages to Design the New Factory X

3.4.1 Design Stage 1: System Requirement and Constraint Analysis

Design Stage 1 was required to address the production size, and the external conditions that the designated yam bean factory must satisfy. This was performed as follows:

3.4.1.1 Production Requirement of the Yam Bean

The production requirement was defined by the specifying total expected yearly production volume (PV) for the yam bean based on the demand forecast.

3.4.1.2 Compliance to Statutory Requirement

The local codes of practice that related to the food factory designs, premised and the production of drinks were listed and reviewed in order to ensure the design of the factory system will comply with the statutory requirement. The codes and related

legislation were requested from the local authority (LA) which is Majlis Perbandaran Kajang and also searched from the Food Safety and Quality Department (FSQD) website in Ministry of Health.

3.4.1.3 Site Analysis

The analysis was done based on the basic data of the property e.g. exact location, property size, shape, contour, building height, floor loading, traffic access, available utilities and market proximity. The purpose of this analysis was to determine the constraints and advantages that would affect the factory design.

3.4.1.4 Plot Plan

Upon completing the site analysis, the plot plan was sketched as to provide the first overview on the arrangement of the factory. The food processing activities was decided to be accommodated in a single-storey floor. The property was oriented to have access to the existing road (where available) and the building facade would face the main road for show-purpose of company's signage. The data on the existing utility supply (voltage supply, water pressure, communication line) was checked and detailed out with the services provider. The services were checked whether they conformed to the local authority requirement on food processing (DBKL, 2012).

3.4.2 Design Stage 2: Production Planning

Design Stage 2 was required to plan the production as to meet the system requirement. The following planning activities were performed.

1) Understanding of products

The products was defined in term of the composition of yam bean snack, primary packaging type and size as well as the secondary packaging. This was aided by the

product specification and a model shop sample that was obtained from Company X . Taking into account the unique characteristics of food materials, other attributes such as shelf-life, perishability, and nutrients compositions were also defined (Manzini and Accorsi, 2013).

2) Development of Production Program

Production Program was developed by tabulating an annual production output for the yam bean snack product. The content of Production Program includes the types of product, unit sale size, primary and secondary packaging, forecasted production volume for one year period in the first phase.

3) Development of batch formulation

The product formulation or the recipe was obtained from company X and was then reformulated as the batch formulation with one batch size (*B*) was decided to be 80 kg for yam bean, 24 kg for red sauce, 24 kg for soy-based sauce and 24 kg for roasted nut. This batch size was decided by considering the commonly available small-scale machines related to fresh-cut, sauces and nuts production that can be found in the industry. This also ensures the availability of the equipment to be purchased from the market. Other information that was needed was the listing of the materials sources, material specifications, the total production of product produced every day, the packaging and identification number of the product produced and the preparation of the inspection of incoming and the shipping process of the product. The quantity of material required per batch must consider the estimated yield and losses after the processing complete. This is done by or using industrial estimation for yield and losses based on historical production data.

4) Calculation of production days capacity per year (D_P)

D_P determines the number of available days for production activities and was calculated using Equation 1.

$$D_P = D_W - (D_{M/R} + D_{Clean}) \qquad \textbf{Equation 1}$$

Whereby,

D_W = 300 days (average working days/year)

$D_{M/R}$ = number of days for scheduled maintenance (10 days)

D_{Clean} = number of scheduled cleaning days (10 days)

5) Daily production time, T_{DP} using Equation 2.

$$T_{DP} = (S_D \times T_{Shift}) - T_{Idle} \qquad \textbf{Equation 2}$$

6) Calculation of production hour capacity per year (T_P)

T_P is the yearly production hours capacity and can be calculated using Equation 3.

$$T_P = D_P \times T_{DP} \qquad \textbf{Equation 3}$$

7) Calculation of number of batches per year (n_B/a) using Equation 4.

$$\sum n(B)/a = \left(\frac{PV}{B}\right) \text{ in batches/year} \qquad \textbf{Equation 4}$$

With,

PV = Production volume/year (kg/year)

B = Batch size

8) Batch cycle time(t_{BC})

The batch cycle time, t_{BC} is the time taken to complete one cycle (batch) of production and was calculated based on method suggested by Jung (2010) using Equation 5.

$$t_{BC} = \frac{T_P}{\sum n(B)/a} \text{ in hr/batch} \qquad \textbf{Equation 5}$$

9) Number batch per day, B_D using Equation 6

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$$B_D = \frac{T_{Dp}}{t_{BC}} \qquad \textbf{Equation 6}$$

10) The actual number of production days, D_x

D_x is different from D_P as D_X determine the actual number of days taken to complete the total number of batches per year (nB/a) while D_P tells us the number of available days throughout the year for working on the production (time capacity). D_x was calculated using Equation 7.

$$D_x = \left(\frac{n(B)\,/a}{Number\ of\ batch\ per\ day}\right) \qquad \textbf{Equation 7}$$

11) The utilization of production time capacity (U_T) is determined as the ratio of the actual number of production hours (T_X in hours/y) relative to the production days hours (T_P in hour/y). This is given in the Equation 8 as adapted from Groover (2007).

$$U_D = \frac{D_X}{D_P} \qquad \textbf{Equation 8}$$

When $U_T \geq 1$, this implies the D_X has exceeded D_P. Thus, the production activities are not able to meet the demand in a timely manner. This requires the company to consider decreasing the batch cycle time or increasing the batch size, number of shift, operator, machines and duplicating the production line. The ratio value of 0.6 to 0.8 is recommended since this means the production capacity is not too "tight" and able to meet the customer deadlines as well as cater the surge demand (Saravacos and Kostaropoulos, 2005).

3.4.3 Design Stage 3: Process Planning

Design Stage 3 is required to develop the processing steps for the production of yam bean snack. The planning steps were executed as below:

1) Process flow development

This was done by firstly discussed with the company on their existing process. Based on their requirement for the process function, operation, technological requirement and products improvement suggestion, a new process flow was developed based on the review on the existing processes for the yam bean snack. The testing of the process flow was carried out by the company themselves and was not included in this scope of the project.

2) Process technology

The common technology for each individual process step in the process flow was researched. The parameter and operation were selected based on process purpose. Illustrations on the common processing technology are included during the process planning. Full automation was proposed for the process with the high number of Work-In-Progress (WIP) to reduce throughput time such as packing or filling.

3) Process flowsheet

Process flowsheet was developed by using the American Society Mechanical Engineers (ASME) flow diagram concept since the ASME symbol allows the designer to visualize the state of operation, whether "storage", "process", "movement" or "quality control" (Jung, 2010). This enables the designer to detect whether the designated process flow has too many movements, recurrent storage or over-processing that can prolong the throughput time and consequently improve the process flow.

The sheet was separated into 5 divisions: receiving, raw material storage, processing and packaging, finished product storage and shipping. The arrangement of the process steps based on these divisions enables the designer to detect any material flowing in

crisscross or backward manner, which could imply lagging in throughput time and hygiene issue (Hasnan et al., 2014).

3.4.4 Design Stage 4: Selection of Machines

At this design stage phase, the selection of the machines with suitable specifications that fulfil the functions, capacity and also safe to operate with the certificate from Standard and Industrial Research Institute of Malaysia (SIRIM) were chosen. Hygienic design of machines and machine's feature were also the aspects need to be considered in the selection process as it can promotes sanitation practice and maintenance cost of the production. The selection of machines were performed based on the following procedures:

1) Machine type, function and operational feature

Machines with correct function and operation were selected as to meet the process specifications obtained from Design Stage 3

2) Machine capacity and quantity

The capacity and number of machine as to meet the Production Program were calculated and had a reserve capacity with the range of 20 to 40% (Baker, 2013; Jung, 2015; Saravacos and Kostaropoulos, 2015). The calculation method was as below:

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Calculation procedure for machine capacity

Two types of machines are considered for capacity planning namely, 1) machine that runs continuously such as a filling machine and 2) machine that has to be loaded batch wise to run such as abrasive peeler. The calculation of the capacity planning has to take account on the following SME product characteristic:

- SME usually use standard universal machines that are available in the market (Baker, 2013)
- SME must be able to cater sudden increase in demand since their customer usually vary from time to time and thus their demand also varied. Based on Saravacos and Kostaropoulos (2002), Jung (2015) and Baker (2013), it is useful to provide 20% to 30% reserve capacity for machines.
- It is common for the food factory to conduct overlapping operations, with no duplicate equipment (for SME) (Baker, 2013). Hence, the batch cycle time (t_{BC}) is the time needed to complete the slowest individual process (Fuente, 2011).

With the above assumptions, the capacity of continuous machines (MC_{CM}) is calculated using Equation 9, whereby k represents the reserve capacity percentage e.g. 30%. $\sum Q_i$ is the total annual throughput that go through the machine, while $T_{M,E}$ is the annual estimated machining time as allocated based on time study techniques (time measurement at the existing production, historical data or using standard time based on expert opinions.

$$MC_{CM} = \frac{\sum Q + k\left(\sum Q\right)}{\sum T_{ME}} \qquad \textbf{Equation 9}$$

Equation 10 provides Q when the annual numbers of batch ($n(B)/a$) for that product assortment and its throughput quantities (q) that go through the machine are known.

$$Q = q \times n(B)/a \qquad \textbf{Equation 10}$$

$T_{M,E}$ is the sum of machining time ($t_{m,E}$) taken to process the throughput for all product assortments. Since the machines are not yet available during the design, the time study technique is again proposed to estimate $t_{m,E}$ based on Van der Vorst (2001). Van der Vorst (2001) proposed that every process should time window in order to ensure the required customer lead time can be met. The estimation of $t_{m,E}$ must ensure that $t_{m,E} \leq t_{BC}$, (since t_{BC} is the time to complete the entire batch). Usually $t_{m,E} \approx t_{BC}$, when the machine is loaded with the highest WIP (Prajapati and Deshpande, 2015). Equation 11 provide the calculation of $T_{M,E,}$ when the annual numbers of batch ($n(B)/a$) for the product assortment are known.

$$T_{M,E} = t_{m,E} \times n(B)/a \qquad \textbf{Equation 11}$$

The capacity of batch wise machines is referred to the filling level or the maximum load capacity. The selection of load capacity should considers the material's density and must be enquired to the machine supplier. The calculation of batch wise capacity requires the designer to determine the highest throughput quantity (q_{max}) that should be loaded into the machine at one time. The q_{max} should represent 80% of the actual machine loading capacity (MC_{BM}), giving the reserve capacity of 20% (Hasnan et al., 2016). Hence, Equation 12 is used to calculate MC_{BM}.

$$MC_{BM} = q_{\max}/0.8 \qquad \textbf{Equation 12}$$

3) Machine configuration

This was addressed by specifying the preferred system interface, control logic, control panel layout and machines accessories (Browser, 2013). Since SME usually experience space constraints, the following machine length can be a guide: ≤ 2.4 m requires small footprint, up to 3.6 m for medium and 4.8 m requires large spaces (adapted from AVI, 2010).

4) Material handling specification

The required material handling equipment was analysed based on checklist provided by Stephens and Meyers (2013). The analysis considered the method to move materials between machines, workstation and storages. Standardized material handling equipment are desired to minimize the number of trips between two stations with the same amount/size of materials.

5) Standard compliances

In Malaysia, the design and fabrication of any machine need to comply the product certification scheme by Standards and Industrial Research Institute of Malaysia (SIRIM). Less breakdowns can be expected from the certified machines. For imported machine, the SMEs need to verify SIRIM's acceptance of the standards and codes carried by that machines.

3.4.5 Design Stage 5: Processing Facilities Design

The zoning and room planning has been designed in this stage to have an efficient production area. The location of the every machine is planned according to the suitability of processes involved in the production area.

3.4.5.1 Zoning and Segregation

The zoning is done by dividing the factory spaces into four major functions namely storages, production (manufacturing), receiving and shipping. After that, the four major spaces are further segregated into individual rooms. Individual rooms are separated between high-risk area and low-risk area (Van Donk and Gaalman, 2004; Holah and Lelieveld, 2011).

Low-risk area accommodates the processing activities that take place before the decontamination or kill-step (Holah and Lelieveld, 2011). High-risk area accommodates the processing activities that take place after decontamination or kill-step, where recontamination must be strictly prevented (Lelieveld et al., 2014). The room segregation will results in a Room List.

3.4.5.2 Room Planning Procedures

Schematic room layout is developed and the layout planning are proposed according to storages, production and transition (receiving/shipping).

Storage Room: Storage room is to be planned based on unit load system and consideration on clearance requirement for hygiene (GMP). The unit load can be packaging itself or any equipment that hold the goods together such as trays, pallets or bags. The procedures are only proposed for shelving and floor-standing storage as these are reported to be the widely applied storage system in the processing of convenience food and small scale processing (Hui, 2014; Schwarz et al.,2011).

Production Room: Production room is to be planned based on consideration space for individual workstation and then all the workstation will be combined to form a single production room.

<u>Method to design storage room</u>

1) Determine the storage capacity
2) Select the storage method either shelving method or floor-standing method.
3) Determine other storage equipment such as trolley
4) Determine the number of operators and doors that can access into the room.
5) Determine the room dimension.
6) Determine the temperature and the humidity of the room

Method to design production room:

1) Determine the process of the productions involved.
2) Identify the number of machine used and machine size based on the process.
3) Design the layout of the productions room with onwards flow of productions and determine the number of operators needed for the process. The layout must be followed the requirement of GMP. The requirements of the hygienic design of the factory are listed below:
   i. The distance of the machine and other adjacent items is minimally 1 metre.
   ii. The distance of the machine and another machine must be at least 0.45 metre.
   iii. The width of working space is at minimum 1 m (Jung, 2010).
   iv. The working space of the operator must at least has the width between 0.875 to 1 metre.
4) Determine the number of operators used and doors that can access into the room.
5) Determine the room dimension.
6) Determine the temperature and the humidity of the room.

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3.4.6 Design Stage 6: Auxiliaries Facilities Design

There are four types of auxiliaries facilities required to be design in Design Stage Six. The auxiliary's facilities are personal hygiene facilities, production office, laboratory and service room. In this study, the following auxiliary facilties are chosen to be made available in the factory:

1) Personal hygiene facilities: toilets, change room, hand-wash station. Break room is not provided and operators are not allowed to eat within manufacturing premise.
2) Service room: Tool storage room, cleaning room for utensils, chemical storage, electrical switch room waste water treatment .
3) Administration: The office are located at first floor and will not be designed in this study. The provision of sufficient floor space is about 8 – 10 m^2 floor space per officer.
4) Laboratory for Quality Control.

3.4.7 Design Stage 7: Space and Manpower Allocation

All rooms from Design Stage 5 and 6 are compiled together to ensure that the production area is sufficient to be operate. After that, the manpower such as number of staff required at each workstation is allocated based on the task required at unit operations. Other task that need to have space and manpower allocation is engineering and maintainance, quality assurance and administrative.

3.4.8 Design Stage 8: Layout Design

A good layout of the factory is the important criteria for the food factory to have a Good Manufacturing Practice (GMP) certificate which ensure the factory have a smooth flow of the production. The position of each auxiliary's facilities,

production zone and process flow of the yam bean from receiving of raw materials until the shipping of the product must be located according the GMP requirement.

Steps to design the factory layout

1) Determine the number of rooms and the facilities needed in the factory.
2) Segregate the rooms and determine the zones from each room.
3) Identify the room locations in the factory layout based on their priority to the productions.
4) Use onwards flow and spine plant layout to design the rooms and the facilities inside the factory.

The onwards flow is a flow where requires the materials and operators to move onwards starting from the receiving area to the shipping area. This flow can prevents the cross contamination to occur on the food processing productions since the flow are onwards (Baker., 2003; Bonne., 2005; Clarke., 2009). Moreover, the adjacency of the rooms can be determined based on the functions of the rooms and the auxiliaries facilities can be designed based on the movement and requirement of the workers inside the factory.

Spine plant layout is a type of layout that have a main aisle called "central spine" with the workstations whether it located on either side of the factory (Langevin et al., 1997). The central spine is a space or area used for the operators or materials to move between rooms or a temporary space for WIP (Langevin et al., 1997; Tompkins et al., 2010). Spine plant layout used onwards flow inside the factory and the room segregation based on their functions to the productions of the factory. Besides that, the individual rooms and the layout of the factory did not have a fixed size as long as it fit into the spine aisle and cross contamination did not occur. For the limitations, the receiving area was used as the starting point of this layout and the rooms are place according to

the closeness relationship. The rooms also can be located at the opposite of central spine if there any size constraints as long as the process of designing layout did not causing the cross contamination to occur (Hasnan et al., 2018).

3.4.9 Design Stage 9: Utilities Requirements

For the last design stage, the utilities requirements of the factory such as ventilation system, lighting health and safety, piping, compressed air, electrical appliance, water supply waste water treatment are determined based on the capacity and the requirements needed in the factory and it is not included in this scope of project as it will be suggested for future work based on the current developed design.

3.5 Phase 3: Project Monitoring

After the design stages was completed, the next steps were the design review by the company and the design analysis to test the productivity improvement and the compliance to hygienic design.

3.5.1 Design Review

The resulted design specifications of the new factory was presented to the Company X comprising of design and planning outcomes from Design Stage 1 to Design Stage 9 namely 1) System Requirement, 2) Production Plan, 3) Process and Technology, 4) Machine Capacity and Selection 5) Processing Facilities Design, 6) Auxiliary Facilities Design, 7) Space and Workforce, 8) Layout and Site Plan and lastly 9) Utilities Plan. Improvement were made based on the Company's input and were finalized in Chapter 4. The design specification were analyzes using simulation analysis and hygienic analysis.

3.5.2 Simulation Analysis using Flexsim Express Software

FlexSim express software is a simulation modelling software that used to simulate the overall process based on the calculated capacity. Through this simulation process, it can run the process and show whether the process and the capacity of the designated factory are suitable within the output needed from the factory. In this project, the model of the existing and New Factory X were developed using FlexSim 3D model interface. The operation of both models were simulated and analyzed to evaluate the productivity improving in the new factory compared to the existing factory. The new factory model was build based on the resulted design details in Section 4.2.1 to Section 4.2.9.

3.5.2.1 Development of the current model and simulation run

Model interface of FlexSym consist of modelling space at the centre, main menu, library, tool bar, simulation control bar and quick properties as shown in Figure 3.6.

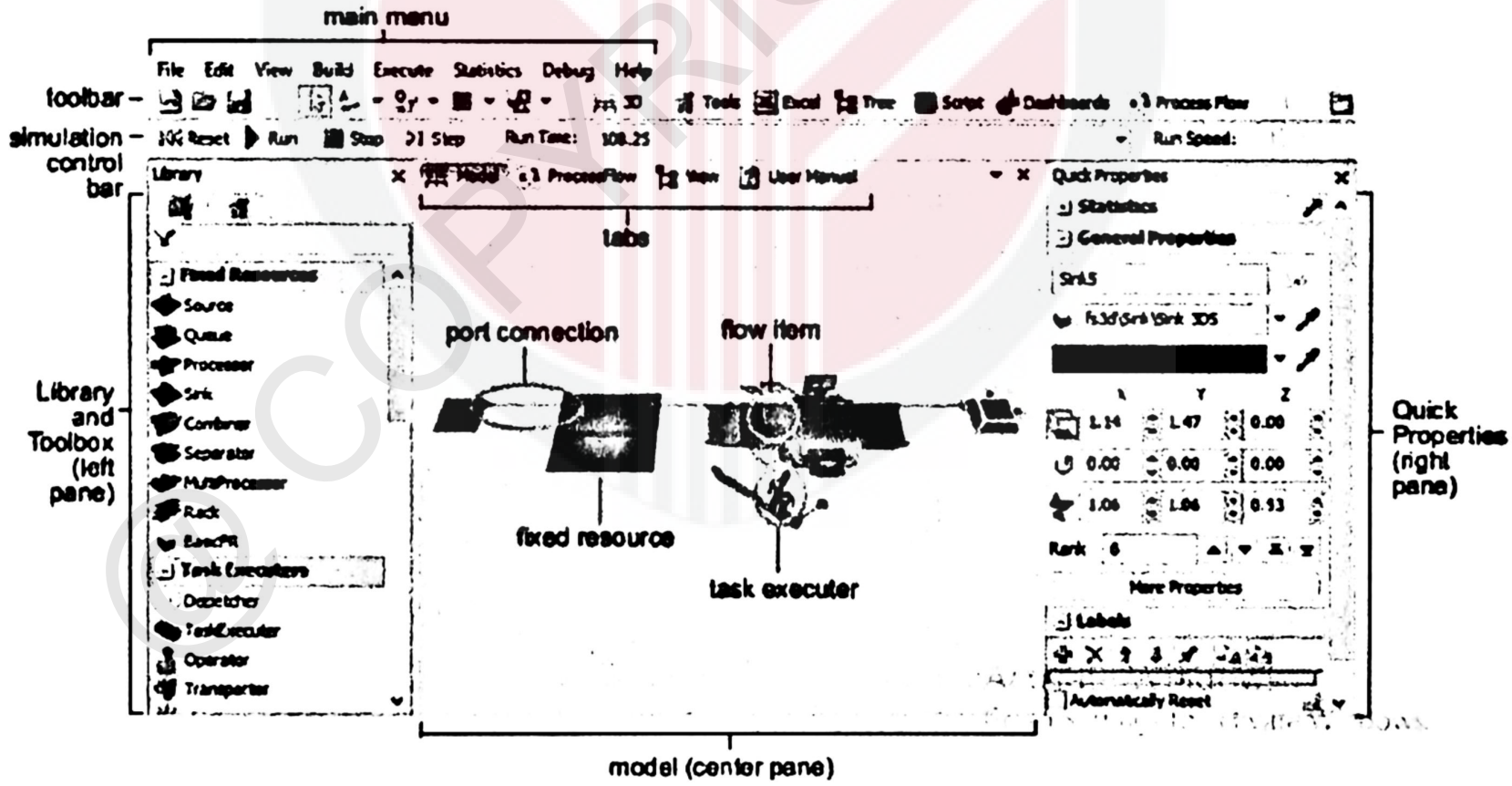

Figure 3.6. 3D Model Interface

Time and space in the simulation environment are dimensionless until the user decides what the dimensions should be. To change the defaults go to the File / Global Preferences / Environment and select the desired units. FlexSim then has to be closed

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and reopened for the change to take effect; however, it is best to decide on the units prior to building a model and set them based on the following means.When starting a new model, a screen appears, as shown in Figure 3.7, showing the definition of units.

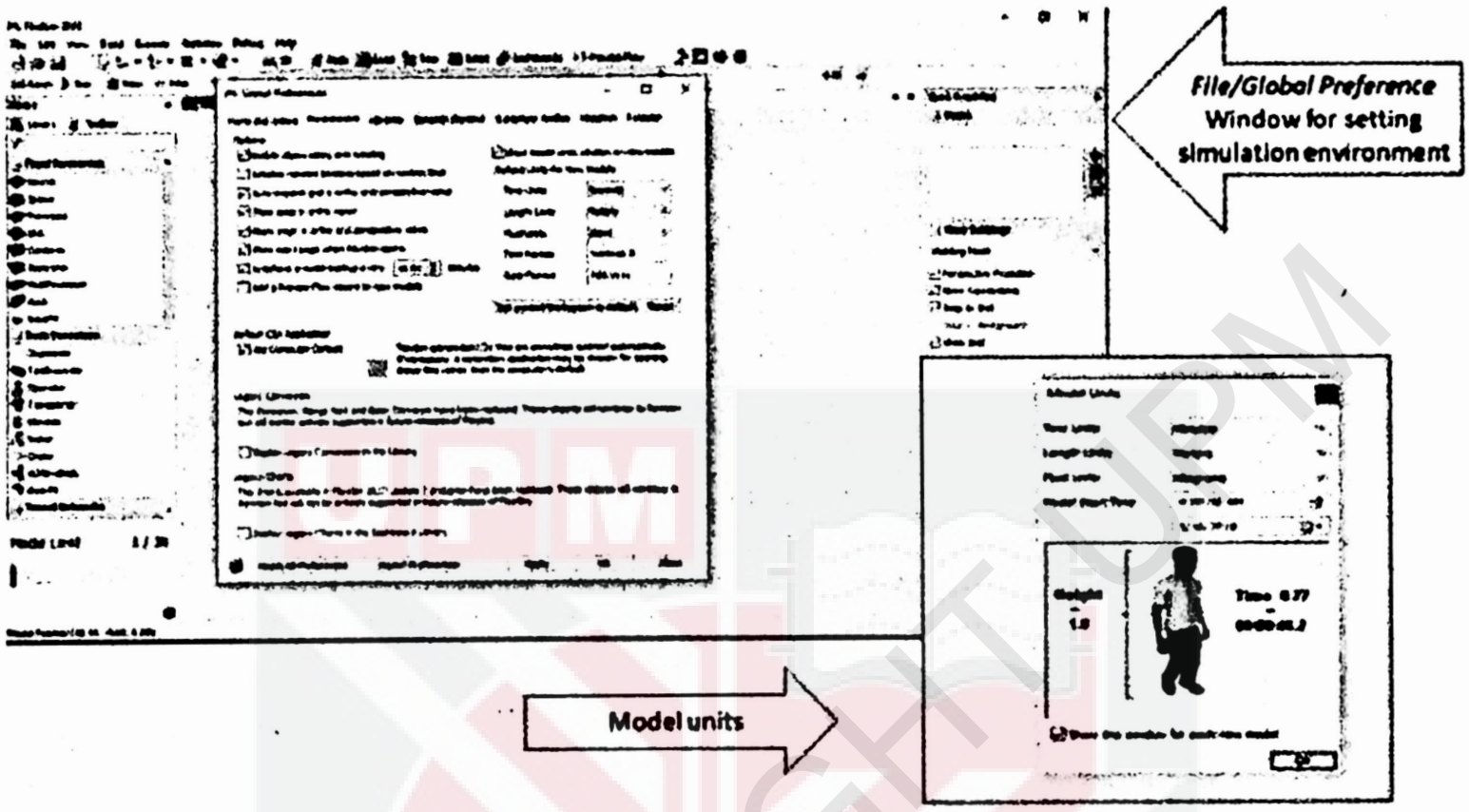

Figure 3.7. Simulation setting

The values are used during some reporting and internal calculations. All data input for the model should be consistent with these units. For this study, the time unit was set in minutes and therefore all the related time setting such as the time between arrivals and cycle time for a processor would both have to be expressed in minutes. As a result, statistics that are generated the simulation, such as the amount of time a processor is operating, will be interpreted in minutes. Once selected, the units may not be changed until a new model is opened. The units for a model are saved with the model file.

Space is also dimensionless. The default unit of space on the simulation layout screen is one grid unit of size 1x1x1. This study has decided the space units to be in meter. Equipment are scaled appropriately based on true dimension. Movable items, such operators, have speed values assigned to them as the number of grid units (in meter)

travelled per clock unit (in minute). Consistent data values are critical to the success of a simulation.

Flowitems interact with objects in a simulation, whereby in this study are the food materials that moves through the factory system. Objects perform an operation, create a delay, or move the items. Thus, a simulation model is simply a collection of these objects and flowitems put together in such a manner as to simulate the behaviour of a system. In order to develop the 3D model of the factory, it was important to understand the objects in the 3D Simulation Model, whereby they are the basic building block in the developed model. All the objects that were used in developing the factory models are source, sink, queue, processor,conveyor, combiner, operator and dispatcher.

All the objects can be resized and rotated using Resize and Rotate Object function. The properties of the object can be defined using Quick Properties (single click) or Properties Window (double click). The objects can be connected between input and output ports or between central ports with connecting chain.

3.5.2.2 Data collection and data entry

Below are the data required to build the system model and are entered into the Properties Window (Figure 3.8) of the modelled objects:

- Time for material to enter the production room
- Number and type of equipment at every workstation
- Number of operator at every workstation
- Type of throughput material at machine and its quantity or size
- The sequence in which every type of ingredient enter the machine
- Distance between workstation (in meter) or layout

- Interstation movement of material handling equipment (type, quantity, time)
- Processing time
- Set-up time
- Operator's speed of working

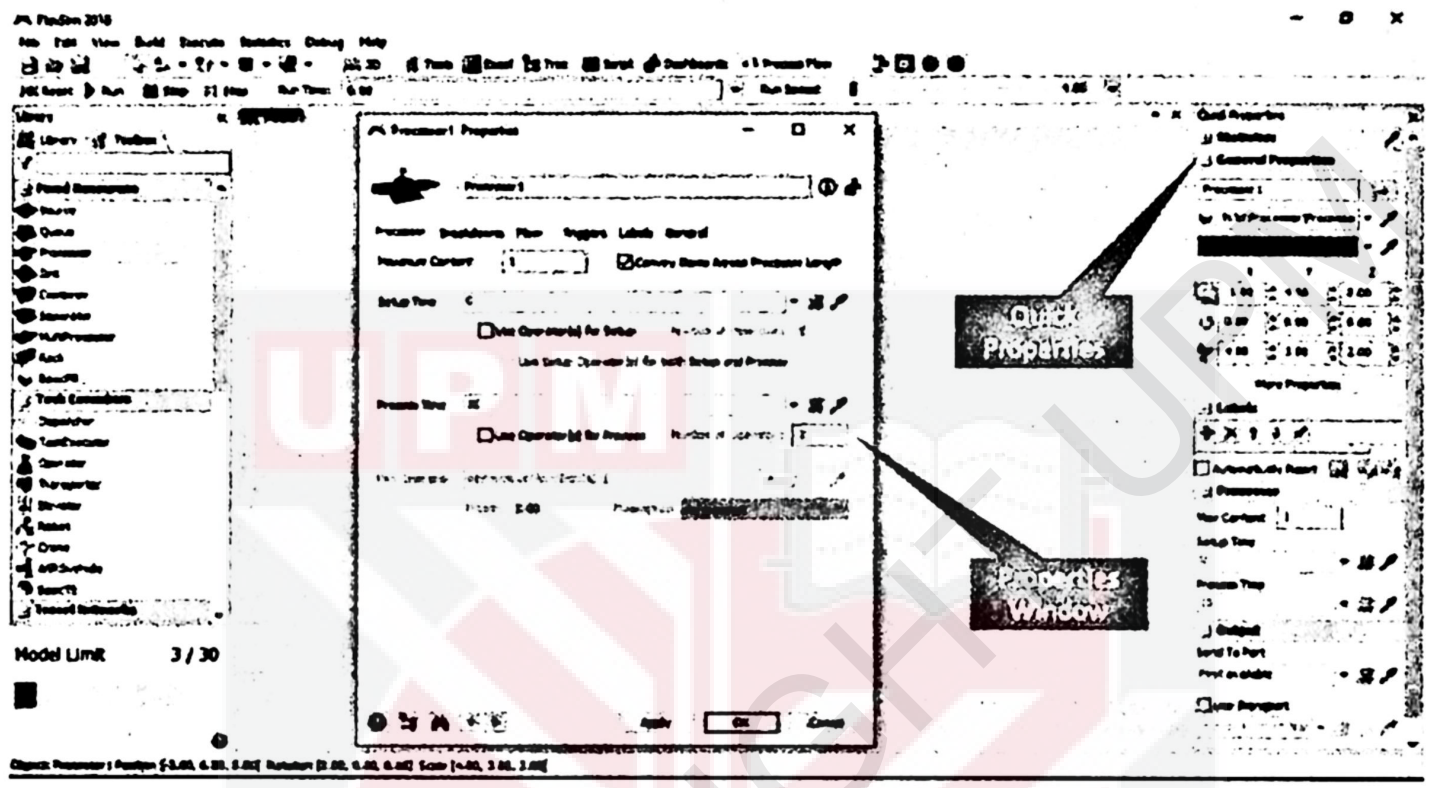

Figure 3.8. Properties Window

Particular attention was given for the processing time, whereby this referred to the time taken for one unit of throughput raw material to be processed by the machine or operator .Exemplarily at washing sink station, the $t_{process}$ is equal to the time taken to wash one batch of yam bean (20 kg) at wash station. At peeling station, $t_{process}$ is referred to finish peeling a batch of yam bean.

In order to obtain $t_{process}$, the data are enquired to the Company X and some are observed during the production. In order to simulate such activity as close as possible to the real situation, a probability distribution model is required to represent the random pattern of $t_{process}$ for every process step. This distribution model is needed by FlexSim to generate the random $t_{process}$ in the simulation run. Based on the literature recommendations, it is found that the triangular distribution is best applied to represent

the random pattern of $t_{process}$, when limited access/control is available to the studied system (Altiok and Melamed, 2007). The triangular distribution requires three parameters for the $t_{process}$: the minimum possible value (a), the most common value or mode (c) and the maximum possible value (b). The triangular distribution assumes that $t_{process}$ values to be in an interval, $S = [a,b]$, with the mode, c, being some point between a and b ($c \in [a, b]$). The likelihood, $f(t_{process})$, increases linearly in the subinterval $[a,c]$ and decreases linearly in the subinterval $[c,b]$, so that the density has a triangular shape as in Figure 3.9.

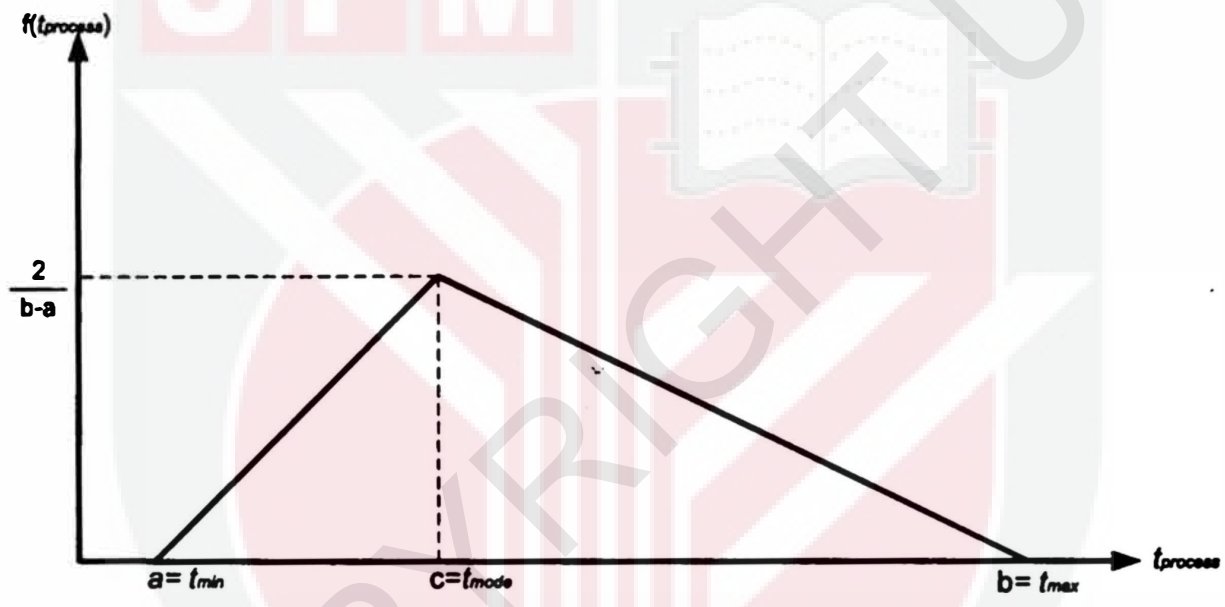

Figure 3.9. Triangular distribution of $t_{process}$

The Flexsim simulation generates $t_{process}$ values based on $f(t_{process})$. Since the mode does not have to be equally between the minimum and the maximum value, the triangular distribution does not have to be symmetric. In this study, the values of a, c and b are enquired or measure at the existing Company X.

3.5.2.3 Simulation run

The current Factory X model was built based on the data in Section 3.5.2.2 and did not include the receiving, shipping and storage activities. This was because the study was aimed to evaluate the production efficiency in relation to the throughput time performance. The definition of throughput time is limited to the amount of time

required to turn raw materials into finished goods on the manufacturing floor and does not include receiving, shipping and storage activities (Bragg, 2011). The development of model applied the "objects" provided by Flexsim. The objects were able to model the manufacturing elements such as food material, machines, operators, processes and workstations and also the occurring event in the production such as the food material entering the production room or workstation, movement of material, batching and finished products in cartons leaving the production room.

Due to the limitation of the trial software, the simulation cannot be run with multiple replication which is cannot be repeated and only run as a single statistic mode. The trial software trial and does not have license of additional features called Experimenter to run the simulation many time. Therefore, need to verify and validate the model with the company. When the simulation runs, the dashboard as in Figure 3.10 was developed to analyse the manufacturing lead time, operator's utilization, waiting time and processing time, which are useful to deduce the productivity of the New Factory X.

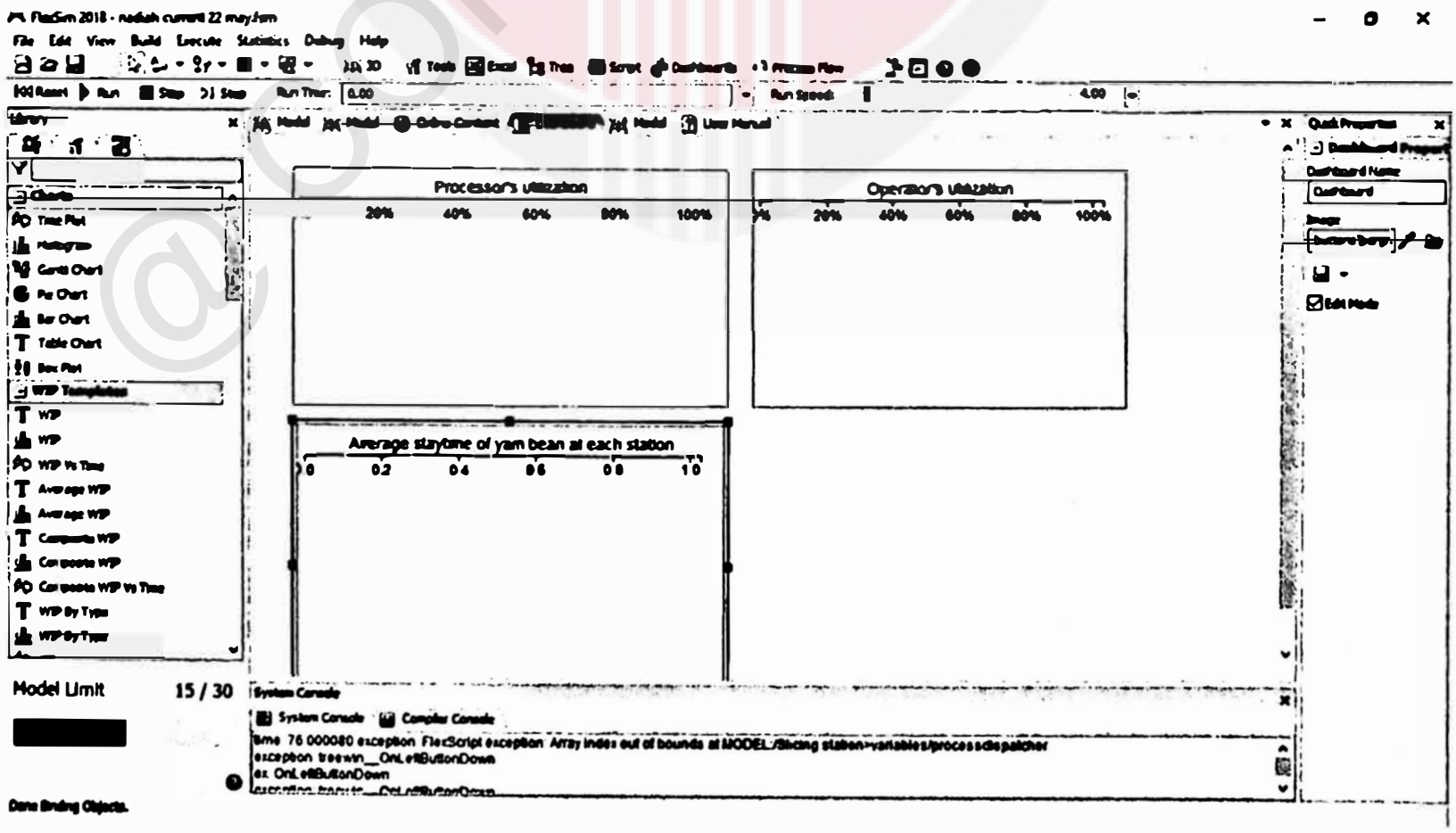

Figure 3.10. Developed Dashboard for simulation analysis

3.5.2.4 Verification and Validation of Factory X Model

The verification was performed to ensure that the model was correctly constructed while the validation was to show that the simulated model could accurately represent the real system. The verification was done based on Little's formula, as in Equation 13, where $\overline{N}$ must be satisfied by λ using the simulation values (Alwadood et al., 2010; Rani et al., 2014). $\overline{N}$ is the average amount of raw material in the system, $\overline{W}$ is the average time spent by raw material in the system and λ is the average rate of raw material entering the system. Rani et al. (2014a and b) as well as Altiok and Melamed (2007) have shown that if the difference between and λ do not exceed 10%, then the system models are considered verified.

$$\overline{N} = \lambda \overline{W} \qquad \textbf{Equation 13}$$

The validation was done by comparing the simulation results for processing times at workstations and the batch cycle time with the actual data obtained at the existing Factory X (Equation 14). The widely applied validity tolerance is 10% namely the simulation output should not deviate by more than 10% of the real system output (Altiok and Melamed, 2007; Rani et al., 2014a).

$$\text{Difference} = \frac{|\text{Simulation Output} - \text{Actual Output Data}|}{\text{Actual Output Data}} \times 100\% \qquad \textbf{Equation 14}$$

3.5.2.5 Development of new model and simulation analysis

Once the model for the current Factory X was verified and validated, the New Factory X model was constructed with the similar modelling approach, but included several modifications due to the developed new design specifcations. The modifications were aimed to reduce the production time and achieved the required productivity (processing time, wait time and move time).

3.5.2.6 Data analysis and design review

The analyses below were carried out to measure and compared the production efficiency between the current Company X and the new proposed model:

1) Production lead time: the total lead time required to finish one batch of production (adapted from Rani et al., 2014a). This also represented the throughput time required for one batch of raw material to be transformed into finished products.
2) Productivity: This is determined based on the ratio of the produced number of finished cartons to the time (adapted from Rani et al., 2014a)

Discussion was conducted in relationship to operator's utilization, processing time at each work station and handling time (setup, queue).

After the design stages was completed, the next steps were the design review by the company and the design analysis to test the productivity improvement and the compliance to hygienic design.

3.5.3 Hygienic Design Checklist Tool Software

The hygienic design evaluation was carried out based on a review of designed drawings and design specifications before the actual building is constructed. The evaluation was performed using Hygienic Design Checklist Tool, developed by the American Grocery Manufacturers Association (GMA), to evaluate whether the designs complied with the GMP hygienic design principles. The existing factory was not evaluated due to confidential issues. The checklist is divided into ten sections:

1 Distinct Hygienic Zones Established In The Facility

2 Personnel and Material Flows are Controlled to Reduce Hazards

3 Water Accumulation Controlled Inside Facility

4 Room Air Flow and Room Air Quality Controls

5 Site Elements Facilitate Sanitary Conditions

6 Building Envelope Facilitates Sanitary Conditions

7 Interior Spatial Design Promotes Sanitation

8 Building Components and Construction Facilitate Sanitary Conditions

9 Utility Systems Designed To Prevent Contamination

10 Sanitation Integrated Into Facility Design

Every section has several criteria to be evaluated and scored. The questions are answered by either "S" for satisfactory, "M" for design is marginally acceptable, "U" for unsatisfactory or "NA" for requirements is not applicable in that design case. Points are automatically given by the tool based on the answers as shown in Figure 3.11. A full score shows the hygienic design is satisfactory, while a score of less than 100% requires the design to be improved (Nikoleiski, 2012). The total points for the checklist is 1000 corresponding to 106 criteria. If the evaluation scores is between 50 to 100%, a continuous improvement is required. The score below 50% shows the hygienic design is unsatisfactory and a redesign is required (Nikoleiski, 2012).

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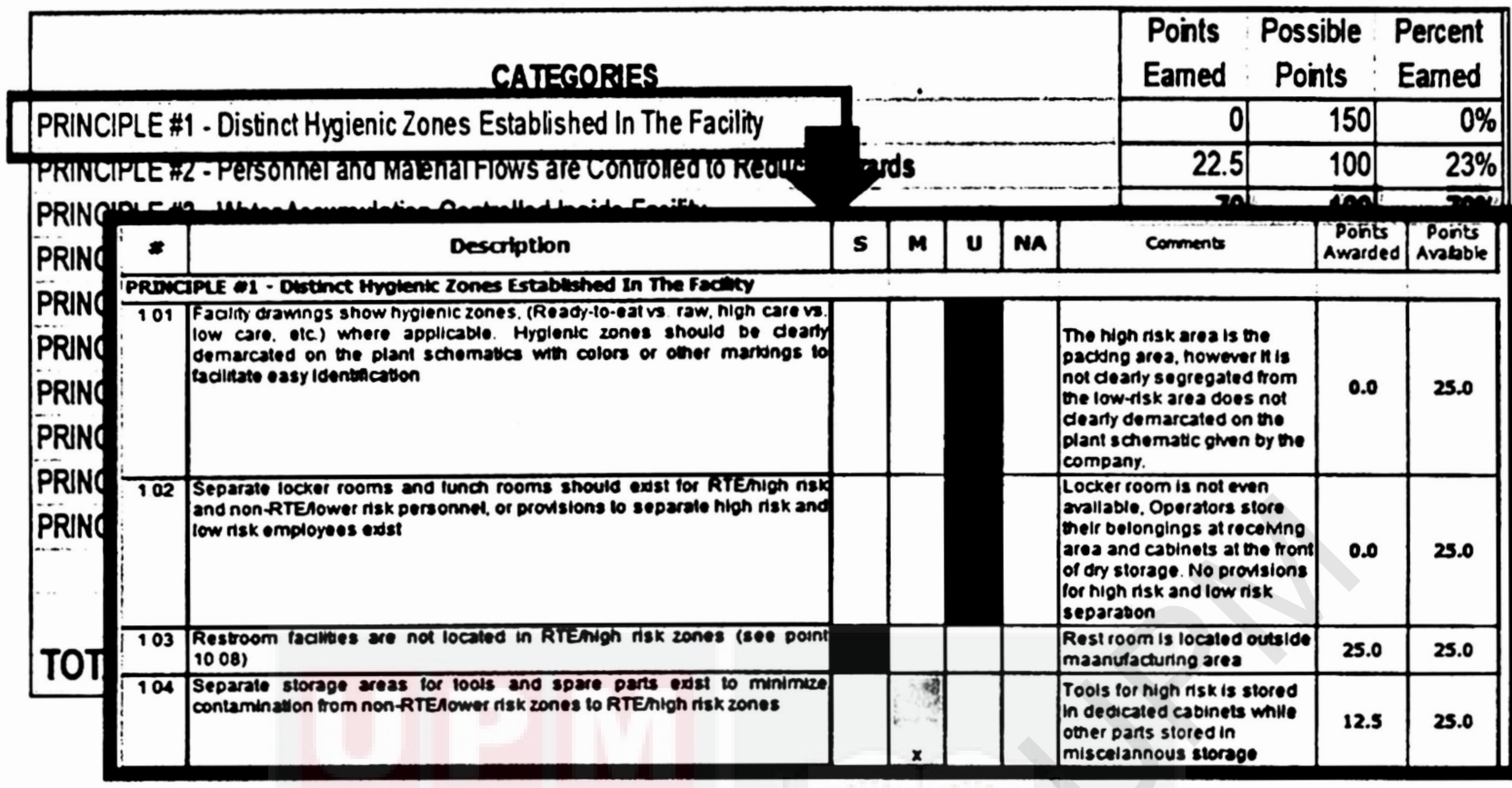

CATEGORIES	Points Earned	Possible Points	Percent Earned
PRINCIPLE #1 - Distinct Hygienic Zones Established In The Facility	0	150	0%
PRINCIPLE #2 - Personnel and Material Flows are Controlled to Reduce Hazards	22.5	100	23%
PRINCIPLE #3 - Water Accumulation Controlled Inside Facility	70	100	70%

#	Description	S	M	U	NA	Comments	Points Awarded	Points Available
PRINCIPLE #1 - Distinct Hygienic Zones Established In The Facility								
1 01	Facility drawings show hygienic zones, (Ready-to-eat vs. raw, high care vs. low care, etc.) where applicable. Hygienic zones should be clearly demarcated on the plant schematics with colors or other markings to facilitate easy identification					The high risk area is the packing area, however it is not clearly segregated from the low-risk area does not clearly demarcated on the plant schematic given by the company.	0.0	25.0
1 02	Separate locker rooms and lunch rooms should exist for RTE/high risk and non-RTE/lower risk personnel, or provisions to separate high risk and low risk employees exist					Locker room is not even available, Operators store their belongings at receiving area and cabinets at the front of dry storage. No provisions for high risk and low risk separation	0.0	25.0
1 03	Restroom facilities are not located in RTE/high risk zones (see point 10 08)					Rest room is located outside maanufacturing area	25.0	25.0
1 04	Separate storage areas for tools and spare parts exist to minimize contamination from non-RTE/lower risk zones to RTE/high risk zones		x			Tools for high risk is stored in dedicated cabinets while other parts stored in miscelannous storage	12.5	25.0

Figure 3.11. Interfaces of the Hygienic Design Checklist Tool

3.6 Phase 4: Project Closing

The design specifications and resulted design analysis were presented to the Company X. Upon approval by the company, the economic analysis based on Return of Investment (ROI) and payback period were estimated. The final report was documented in form of project thesis and supplementary documents such as machines catalogues. Further improvement when required are documented in the report for future works.

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CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents the outcomes of project as follows:

- analysis of the production problems at the current premise
- design outputs for the new factory with solution to increase the productivity and integration of hygienic design for food safety implementation
- simulation analysis for verifying the productivity improvement in the new factory system
- hygienic design analysis to verify the readiness of the new factory system for the food safety practice
- economic analysis on the return of investment and payback period

4.1 Existing Processes of Company X and Problems Related to Productivity and Food Safety

The current production for the slice yam bean begins with the receiving of whole tubers about 40 kg, washing with water, slicing into 1 cm thickness, peeling off the skin, soaking in cold water, filtering, packing into PP bag and boxing into ice boxes. Meanwhile, for the sauces, all the ingredients are prepared and some are fried first, weighed based on the recipe, mixed and cooked together until boiling. Examples of ingredients for the sauces include sesame (must be fried first), shrimp paste, salt, sugar, vinegar and permitted additives. The finished sauces are cooled down to ambient temperature before packing into aluminium back-plated PP bag. As for the roasted nuts, the grinded nuts of Grade A are received from appointed supplier and roasted without oils based on the required time. The roasted nuts are also packed into PP bag after cooled down.

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All the processes are accommodated in a commercial kitchen premise of 5 m x 3.2 m with respective to length and width as shown in Figure 4.1.

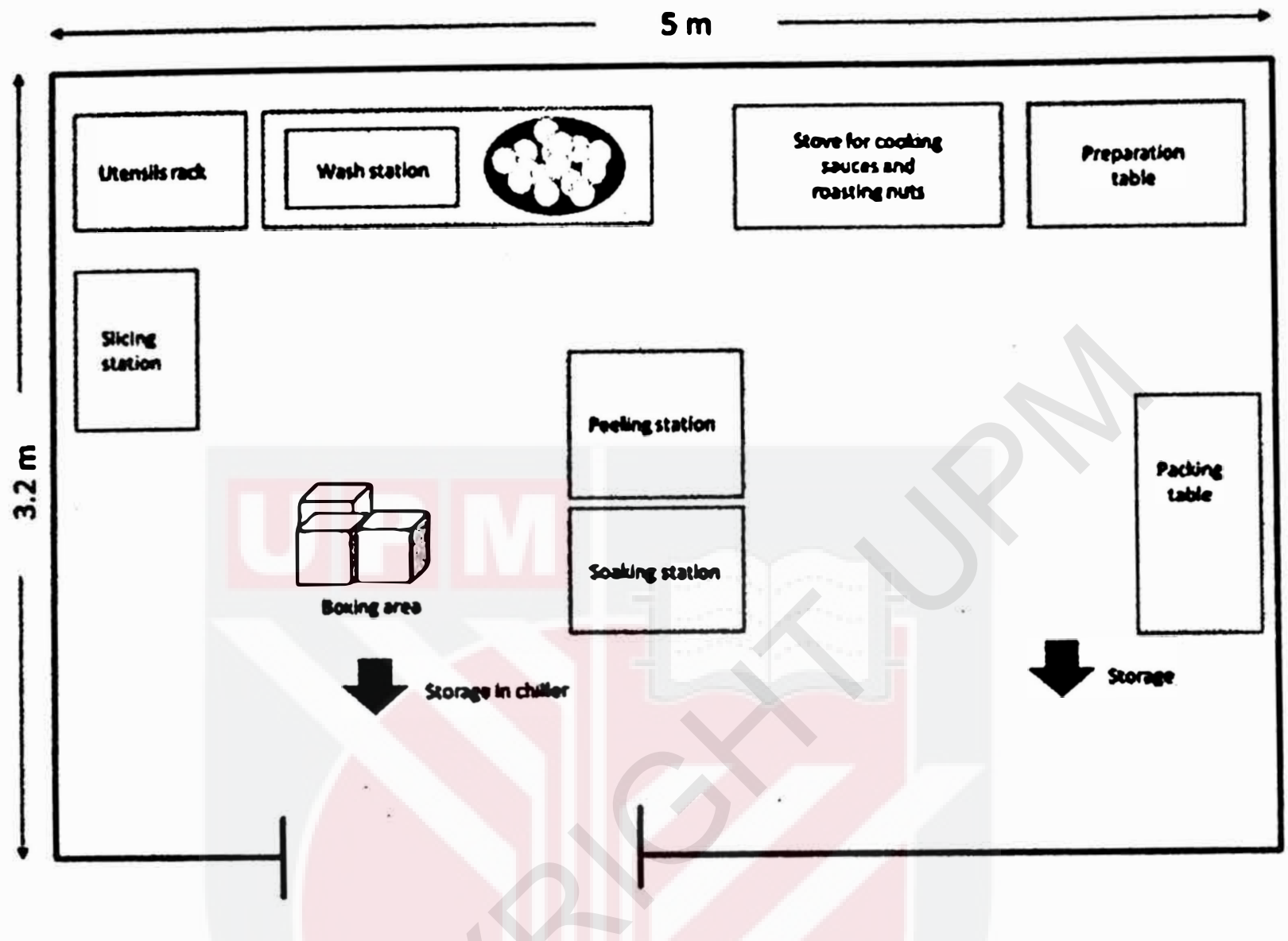

Figure 4.1. Layout of the current premise for yam bean snack production

4.1.1 Problems Related to Productivity and Food Safety for the Sliced Yam Bean

Figure 4.2 gives an overview of the processes involve for producing sliced yam bean. According to the Company X, the complete processing cycle takes about 6 hours to finish (beginning with washing and ending with filtering). The problems are discussed with the company's owner are given as below:

- Manual trimming, slicing and peeling

The trimming and slicing process is done by only one skilled worker and can be exhaustive since normally slices can be required to complete the order. The trimming and slicing process of 40 kg yam bean takes up to 3 hour , while the peeling process

need to be done by at least 2 workers and takes normally up to 20 seconds/slice to finish.

One of the concern is that the peeling was done after the slicing as to prevent the possible finger-cut due to the slippery flesh during the manual slicing. This, however raise the questions of hygiene since the readily cut slices are recontaminated with the peels during the peeling process. In addition, the skin of tuber have only been washed with tap water which can only reduce 0.5 to 2.0 log microbial reduction (Banach et al., 2015).

- Soaking

Soaking is performed in a basin with melted ice to preserve the texture of yam bean. Soaking are done in 2 large plastic basins that hold about 20 kg of slices and takes only 10 to 15 minutes. However, the process is done in exposed container that may recontaminate the fresh-cut, if the surrounding facilities are not kept up with the standard hygiene condition. Poor processed fresh-cut may not have long shelf life and can spoil rapidly in 2 days which is definitely a loss. The same food safety concern can be observed for the filtering process. The filtering process takes approximately 15 minutes and are done by 3 to 4 workers.

- Cold storage

The temperature of the cold storage has never been controlled. Literatures have reported that the fresh cut yam beans are best stored at 0 to 5°C to prevent browning, retard microbial growth, preserve the crispiness and fresh taste.

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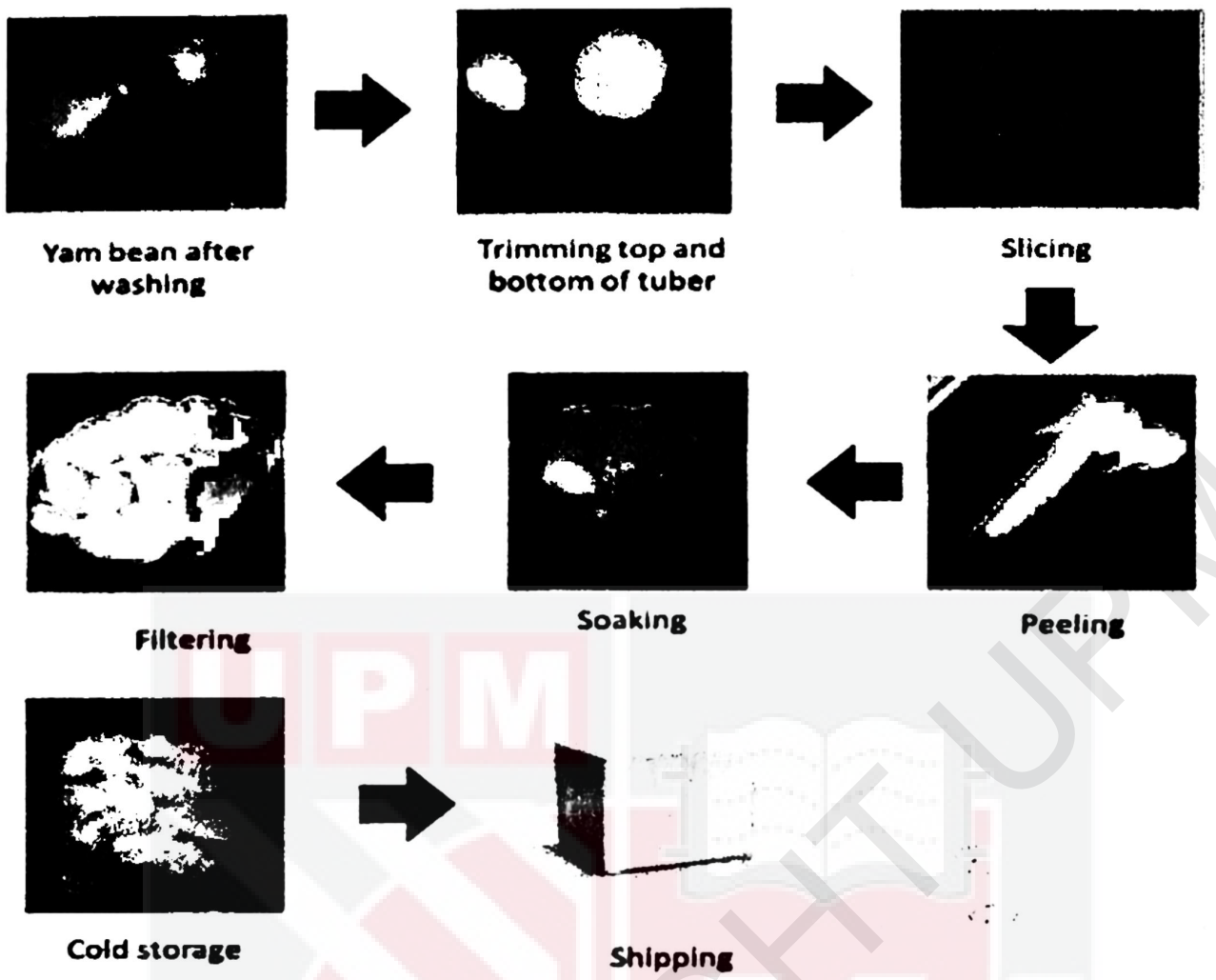

Figure 4.2. Processes for the slice yam bean

4.1.2 Problems Related to Productivity and Food Safety for the Sauces

The processes for making sauces takes about 4 to 6 hours beginning with preparation of ingredients, cooking, cooling and packing. All the processes are subjected to cross-contamination concern since the cooking facilities are in the same area with production of yam bean slices and nuts.

The cooking process of 4 kg sauces takes at least 2 hour and can extend to 3 hours with low heat and the need to stir continuously and manually. The cooking temperature however is not controlled and thus causing the concern on surviving *Clostridium botulinum.* The cooking time can be longer for the soy-based sauce if the soy paste need more time to dissolve completely or if the taste of the sauces are not achieved.

Before packing, the sauces need to be cooled to ambient temperature. There is a concern of possible outgrowth of microbe if they are not sufficiently killed during cooking. As for packing, the task is performed manually and there is a need to improve the labelling of the product since the sauces contain soy which is allergen. In addition,

the packing need to be ensured its integrity, as the improper packing are reported to cause leaking.

4.1.3 Problems Related to Productivity and Food Safety for the Roasted Nuts

Similar to the production of sauce, all the processes are subjected to cross-contamination concern due to improper facilities arrangement. All the nuts (24 kg) takes 3.33 hour to be finished produced. The processes are relatively simple since the nuts are received in readily grinded condition. However, the roasting and frying technique need to be consistent to prevent burnt and preserve the sweet oily taste of the nuts. This task is performed by only one worked that has been trained. Improper packing may lead the nuts being rancid rapidly.

4.2 Design Specification and Production Plan of New Factory X

This section details out the resulted design outcome and production plan for the New Factory X.

4.2.1 Design Stage 1: System Requirement and Constraint Analysis

The main design output of this stage is the system requirement and constraint analysis. The analysis comprised of the production mission statement, compliance to statutory design requirement as well as site analysis and plot plan.

4.2.1.1 Production Mission Statement

Based on the market survey by the sales department, the following production mission statement was derived:

> The designated factory would produce a total of 42 560 kg/y of yam bean snack with 22 400 kg of yam bean, 13 440 of sauces and 6720 kg of roasted nuts.

4.2.1.2 Compliance to Statutory Design Requirement

Compliance to statutory design requirement is enforced by the local authority (LA) for any property to be designed and built. New Factory X is proposed to be located in

industrial zone Selangor, whereby the factory will be accommodated in a low- cost terrace factory (brownfield). Since the factory has not been originally designed for food processing, it is expected that some physical changes are required. Any physical changes due to food processing requirement must be approved by the local authority (LA) in which the mechanical, electrical, structural and landscape drawings must be submitted by certified engineers and architects. The drawings must incorporate the design requirements by the LA. Other physical developments that involve utilities require approval by the organizations such as Syarikat Bekalan Air Selangor (water service provider), Tenaga Nasional Berhad (electricity service provider) and Indah Water Consortium Company (wastewater services). The adherence to local design requirement should go hand-in-hand with the execution of the subsequent design stages.

The legislations that need to be complied are:

- Local Government Act 1976
- Road, Drainage & Building Act 1974
- Licensing, Business Trade and Industrial By-Law (MPKJ) 2007

Meanwhile, in term of food processing, below are the required law and standards to be complied:

- Food Act 1983
- Food Regulations 1985
- Food Hygiene Regulation 2009
- MS 1514 Good Manufacturing Practice Malaysian Standard (MS) 1514: 2009 Good Manufacturing Practice (GMP)
- Malaysian Standard (MS) 14: 2009 Hazard Analysis and Critical Control Point (HACCP)

4.2.1.3 Site Analysis and Plot Plan

The prospect location of New Factory X is the Sg Chua Industrial Zone as given in Figure 4.3. The available volume to be designed is 30 m x 9 m x 3 m and an open aisle

with length about 1.5 m is available at the south side of the premise. The location was not subjected to flooding problem, however, the neighbouring area consists of variety types of factories which could pose hazard to New Factory X. Being an intermediate unit, it is only possible to position the access door through the north and south of the building. The receiving of raw material is oriented to face the existing north service road while the shipping is oriented to face the south road. This position avoided the prevailing wind but criss-cross with the existing drainage that later will contaminate the receiving and shipping activities.

The front facade of the building with the factory's signage is proposed to face the main road since this is the main road. As for the utilities, the potable water line is available from the water company SYABAS. Electricity supply is available from electricity company Tenaga National Berhad (TNB). Communication network is provided by TELEKOM. Effluent drainage is under the management of Indah Water Consortium Company (IWK). Nonetheless, IWK has outlined the requirement for effluent to be treated before disposal. Due to the limited space availability and intermediate characteristic of the standard factory, renovation for structural extension is not feasible in any direction. Such extension could only be feasible through a purchase of any adjacent factory unit in the future.

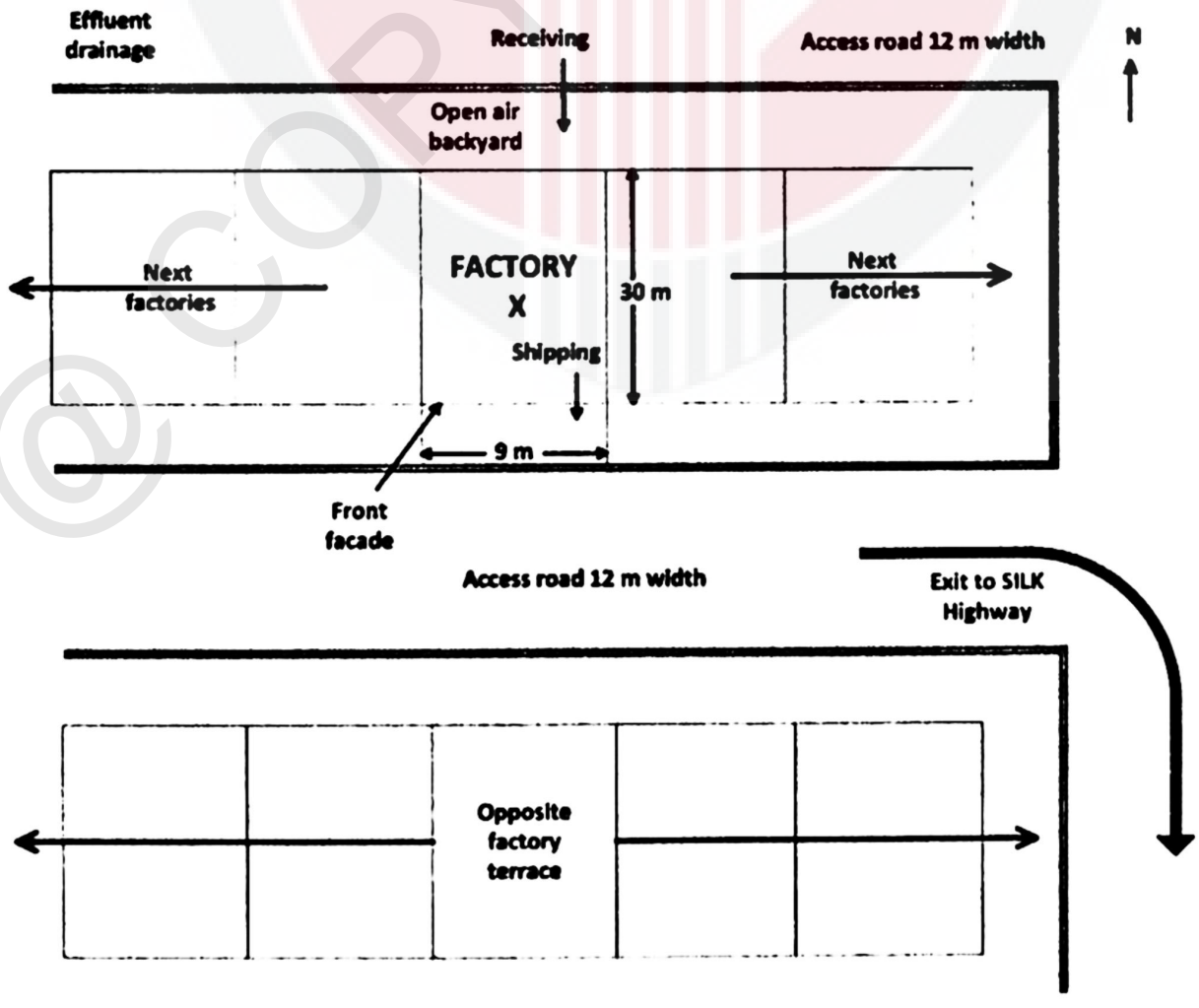

Figure 4.3. Plot plan for New Factory X

4.2.2 Design Stage 2: Production Plan

The main design output at this stage is the Production Plan consisting of the following components:

4.2.2.1 Product Definition

The products of Company X are sliced yam bean (fresh-cut), red sauce, soy-based sauce and roasted nuts (Figure 4.4). The product specification are tabulated in the Table 4.1 and and Table 4.2 below.

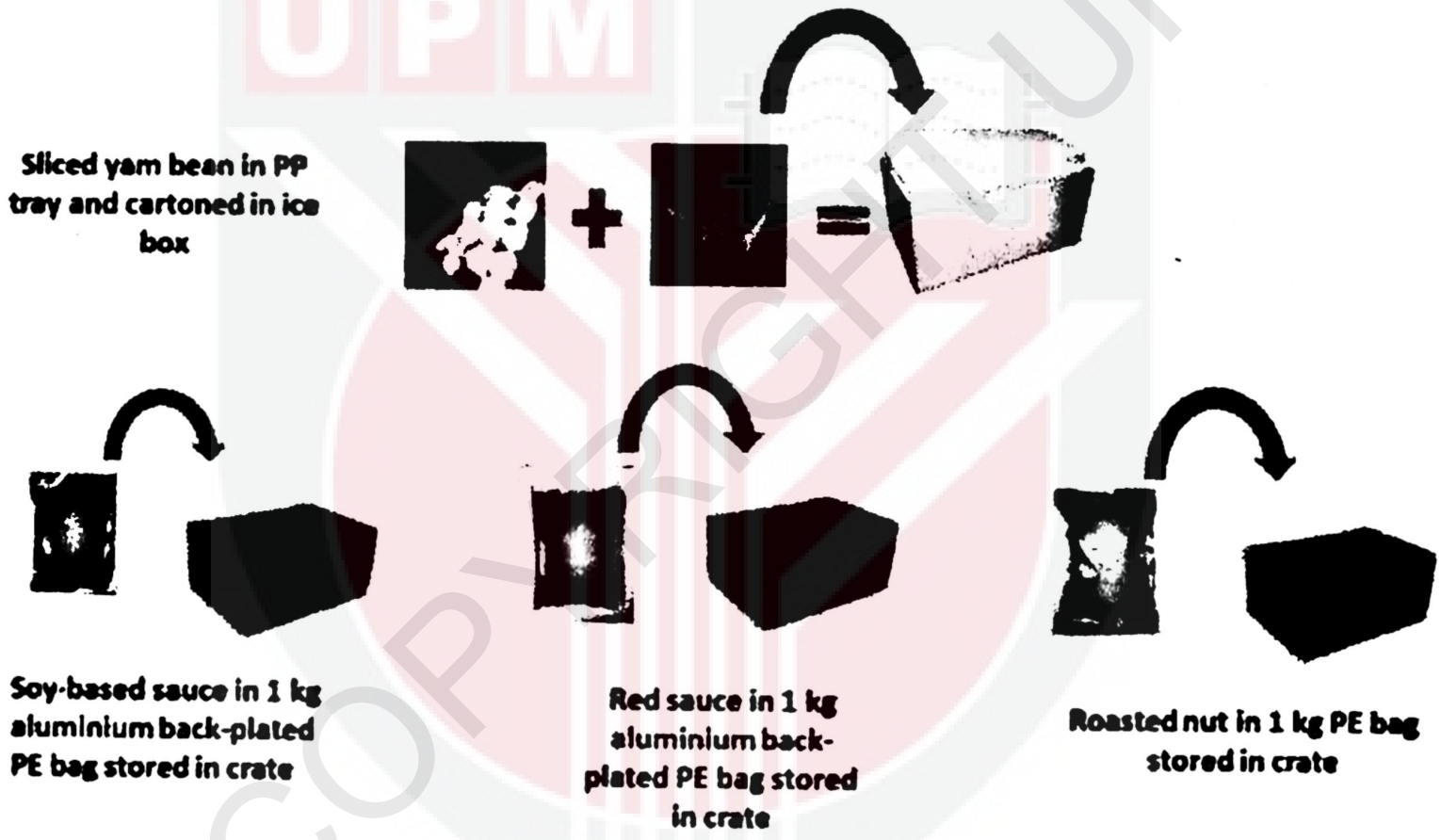

Figure 4.4. Products of Company X

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Table 4.1. Product specification of sliced yam bean

Product name	Mass/ per piece in g	Thickness/ per pieces in cm	Number of pieces in PP tray	PP tray size	Number of PP trays in ice box	Size of ice box
Sliced yam bean	100	1	5	L 17 cm x W 12 cm x 6 cm	20	45 cm x 36 cm x 40 cm

Table 4.2. Product specification of sauces and roasted nuts in PE bag

Product name	Mass/ in kg	Packet size	Number of packet in plastic container	Plastic container size
Red sauce	1	20.8 cm x 17 cm x 3.5 cm	32	61 cm x 43 cm x 32 cm
Soy-based sauce	1	20.4 cm x 13 cm x 3.3 cm	32	61 cm x 43 cm x 32 cm
Roasted nut	1	22 cm x 17 cm x 4.2 cm	24	61 cm x 43 cm x 32 cm

4.2.2.2 Batch Formulation

Batch formulation is given in Table 4.3 to Table 4.6 to give the information on the ingredients required, specification, batch cycle time, batch size and packaging. The batch formulation is useful for production planning, scheduling and inventory planning.

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Table 4.3. Batch formulation for the yam bean slices

BATCH FORMULATION FOR YAM BEAN SLICES			
Product name	Sliced yam bean		
Batch cycle time (h/batch)	4.5 h		
Batch size (kg/batch)	80	Fresh cut	
Batch size (trays/batch)	160		
Batch size (pieces/batch)	800		
Estimated loss or yield	-30%		
Monthly Output			
Product	Number of pieces/month	Number of trays/month	Number of ice box/month
Sliced yam bean	20000	4000	200
Ingredients (Buy)			
Ingredient coding	Ingredients	Qty/batch [kg/batch]	
YB	Yam bean	80	
Packaging (Buy)-Losses 0%			
Packaging code	Packaging	Qty/batch	
PP tray	Polypropylene Tray	160	
Ice box	Ice box	8	
Label	Label	8	

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Table 4.4. Batch formulation for the soy-based sauce

[redacted]		
Product name	Soy-based sauce	
Batch cycle time (h/batch)	2 h	
Batch size (kg/batch)	24 kg	
Batch size (bags/batch)	24 bags	
Estimated loss	-30%	
Monthly Output		
Product	Number of bags/month	
Soy-based sauce	600	
Ingredients (Buy)		
Ingredient coding	Ingredients	Qty/batch [kg/batch]
SP	Shrimp paste	Not to be exposed in thesis
SH	Soy hampas	
CP	Chili powder	
ST	Salt	
SG	Sugar	
W	Water	
SS	Sesame Seed	
Packaging (Buy)		
Packaging code	Packaging	Qty/batch
PE bag	Polyethylene Bag	24
PP Plastic Container	Polypropylene Plastic Container	1
Label	Label	1

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Table 4.5. Batch formulation for the red sauce sauce

Product name	Red sauce	
Batch cycle time (h/batch)	2 h	
Batch size (kg/batch)	24 kg	
Batch size (bags/batch)	24 bags	
Estimated loss	-30%	
Product	Number of bags/month	
Red sauce	600	
Ingredients (Buy)		
Ingredient coding	Ingredients	Qty/batch [kg/batch]
SP	Sweet potato	Not to be exposed in thesis
V	Vinegar	
ST	Salt	
SG	Sugar	
C	Colouring	
W	Water	
Packaging (Buy)		
Packaging code	Packaging	Qty/batch
PE bag	Polyethylene Bag	24
PP Plastic Container	Polypropylene Plastic Container	1
Label	Label	1

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Table 4.6. Batch formulation for the roasted nuts

Product name	Roasted nut	
Batch cycle time (h/batch)	2 h	
Batch size (kg/batch)	24 kg	
Batch size (bags/batch)	24 bags	
Estimated loss	-5 %	
Monthly Output		
Product	Number of bags/month	
Roasted nut	600	
Ingredients (Buy)		
Ingredient coding	Ingredients	Qty/batch [kg/batch]
N	Nuts	24
Packaging (Buy)-Losses 0%		
Packaging code	Packaging	Qty/batch
PET bag	Polyethylene Bag	24
PP Plastic Container	Polypropylene Plastic Container	1
Label	Label	1

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4.2.2.3 Production Program

Currently, Company X has not built any Production Program and conduct impromptu production according to customer order. With the help of company's Chief Operation Officer, an almost monotonous trend in monthly customer demand is identified. These data are used to develop the yearly Production Program as in Table 4.7. The Production Program identified the individual product's production planning annually.

Table 4.7. Production Program for the New Factory X

Product code	Product name	PV/y (kg/y)	Unit sales packaging		Unit sales/year (unit sales/y)
			Types	Size in g/unit sale	
YB	Yam bean slice	22400	PP tray	500 g	44800 trays/y
SS	Soy-based sauce	6720	PE bag	1000 g	6720 bags/y
RS	Red sauce	6720	PE bag	1000 g	6720 bags/y
RN	Roasted nut	6720	PE bag	1000 g	6720 bags/y
	Total production	42560 kg			64960 units

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4.2.2.4 Production Time Planning

The production time plan as in Table 4.8 ensured that sufficient time is available for the factory system to work on the Production Program annually.

Table 4.8. Summary of production time planning

Planning Details	Value	Equation for calculation from Chapter 3	Measurement/ Specification values
Number of production days/year , D_p	280 days/y	1	D_w = the number of working days after excluding holidays (300 days) $D_{\frac{m}{r}}$ = the number of days for scheduled maintenance (10 days) D_{clean} = the number of scheduled cleaning days (10 days)
Daily production time, T_{DP}	7 h/ day	2	S_D = 1 shift/day T_{Shift} = 9 h/day T_{Idle} = 2 h/day
Production hour capacity per year, T_P	1960 h/y	3	$T_P = D_P \times T_{DP}$
Number of batches per year, n_B/a	280 batches/y	4	PV = 22400L/y B = 80 L/batch

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Table 4.8 continued.

Batch cycle time, t_{BC}	4.5 h/ batch	5	$t_{BC} = T_P/(n_B/a)$
Number batch per day, B_D	1.6 batch/day	6	$B_D=T_{DP}/t_{BC}$
Actual number of production days, D_x	175 days	7	$D_X= (n_B/a)/ B_D$
Utilization of time capacity, U_D	62.5 %	8	$U_D = \frac{D_X}{D_P} \times 100\%$

From the production plan details above, the utilization of time capacity, U_D is 62.5 % and thus, 37.5 % of production time capacity is reserved for emergency purpose such as sudden machine break down and shortage of operators. As example, shortage of operators means that if there is not enough operator at sauce or nuts production , the operator from the yam bean production can help the other operator's work rather than sit and do not have works to do.

4.2.3 Design Stage 3: Process and Technology Description

In the new designated factory, there are several new process were proposed. These are given the following sections.

4.2.3.1 Process Description for the Production of Slice Yam Bean

The new processes for the production of slice yam bean begins with receiving of whole yam bean and storage, packaging material storage in separate location, abrasive peeling and washing , conveyor for sorting, manual peeling and trimming , slicing, sanitizing washing , soaking, drying , Modified Atmosphere Packaging (MAP) and metal detector, boxing, labeling, date coding, cold storage snd shipping. The process flow is given in Figure 4.5.

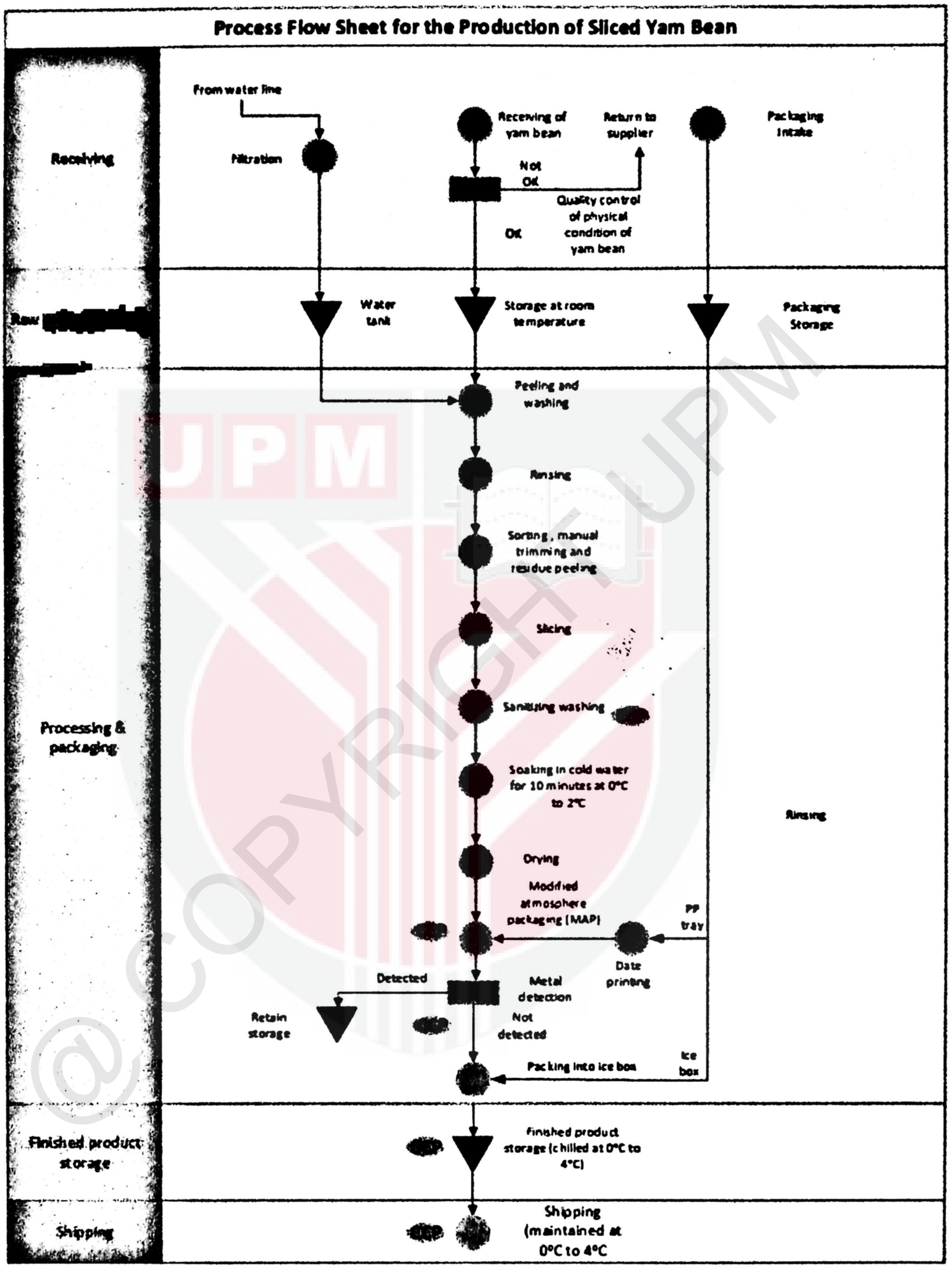

Figure 4.5. Process flow for the production of yam bean slices

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1) Receiving of whole yam beans and storage

Yam beans being received must be clean and sampled for inspection of defects, their required sizes and insects infestation. Written specifications and sample plans must be used for inspection inspect and any variance from the specified quality are returned to suppliers. Upon acceptance, yam bean are stored in the crate and should be tagged with the date of receipt to assure first in first out inventory rotation. All the accepted yam bean are stored in a well-ventilated storage room. The receiving room are equipped with trolley and dollies (L 600 x W 400 mm) to move the yam beans.

2) Abrasive peeling and washing

Abrasive peelers utilize abrasive surface rollers to remove the outer skin from the yam bean (Figure 4.6). The skin is washed away with a fine spray of water. Yields can be variable depending upon the operator as well as tuber size, shape and quality. Abrasive peeling can be very damaging and may result in loss up to 6% (Singh, 1995). After peeling, the peeled yam beans will be prewashed in the peeling tank to further remove soils and skins with water nozzle and brought onto elavator.

Figure 4.6. Abrasive peeling and washing (foodmachine, 2019)

3) Conveyor for sorting, manual peeling and trimming

The sorting conveyor is integrated with the inclined conveyor coming from the prewashing tank and is used to manually remove poor quality yam bean, peel the remaining skins with hand knives and trimming the top and bottom of the tubers (Figure 4.7). The trimmed tubers are placed back on the upper conveyor and proceed to the end of conveyor. Any products exhibiting decay will be discarded as it will contaminate the next sections with microbes, and potentially allow for cross-

contamination of each successively trimmed tubers. If defects and decay are not sorted out at this point, one defect will be cut into many small pieces and be dispersed in a large amount of product making it almost impossible to sort out. Hand knives are kept at this stations and maintained to be clean, sanitary and sharp. The loss is expected to be less than 2% since the quality of yam beans have been controlled at the receiving. This station requires 2 to 3 workers that are trained to detect defect and manually trim the yam beans.

Figure 4.7. Sorting conveyor (foodmachine, 2019)

4) Slicing

The trimmed yam bean are brought to the slicing machine that uses long flat knife blade. Another choice of cutter machine is the one utilizes circular rotary blade, however with large radius of 8 inches. Knife sharpness is a critical factor since dull knives can significantly reduce the shelf life of fresh-cut and thus, replacing or sharpening knives on a regular basis is very recommended. Tracking either the hours of operation on each set of blades or closely visually inspecting the cut surfaces are ways which can be used to consider when blades need to be sharpened or replaced.

5) Sanitizing washing

Properly washing and cooling fresh-cut immediately after cutting is one of the most important steps in fresh-cut processing. The washing of yam bean is carried out through a mesh conveyor whereby the wash water are sprayed on the slices (Figure 4.8). Washing using chlorinated water after slicing helps remove microbes, dirt and

cellular juices at the cut surfaces. Total chlorine up between 50 to 100 ppm with contact time at least 1 minute is sufficient to reduce microbial populations on a fresh-cut produce in the rinse water system. Chlorine dioxide can be injected into the rinse water system and the chlorine level must be monitored during the washing. Excessively high concentrations of chlorine will damage fresh-cut produce and reduce shelf life as well as cause off flavors and odors. Chlorine dioxide functions well over a pH range of about 6 to 10, thus allowing increased mortality of some microbes at higher values and thus acidic condition of the sprayed water is not necessary. Another advantage is that chlorine dioxide does not form chlorinated organic compounds, making it more environmentally friendly. This sanitizing washing process in fresh produce processing is considered a critical control point (CCP) for removing field-acquired contamination.

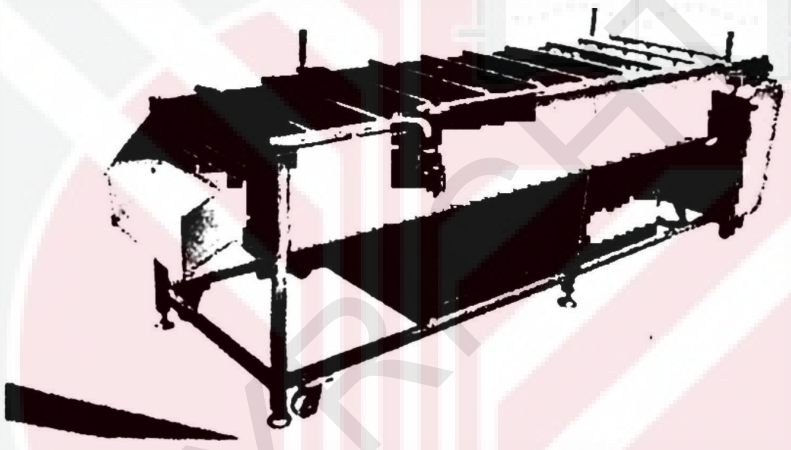

Figure 4.8. Spray wash conveyor (foodmachine,2019)

6) Soaking

The company has requested for the slice yam bean to be cooled down before packing as this has shown to enhance the crispiness of the slices. Thus, the slices are submerged into a cold water tank about 0 to 1°C after the spray wash, allowing soaking time about 10 minutes. After soaking the slices are brought onto dewatering station via conveyor.

7) Drying

The slice yam beans are dewatered using high pressure blower in a semi fluidized bed that can strip water away from the surfaces of yam bean slices (Figure 4.9). The forced air used must be filtered as not to contaminate products.

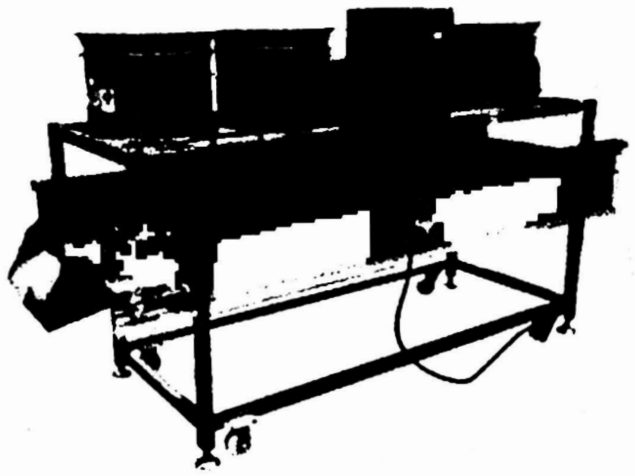

Figure 4.9. Drying using blower (foodmachine, 2019)

8) Modified atmosphere packaging (MAP) and metal detection

All the slices are placed manually in the PP tray with 5 slices per tray. By using MAP technique, the oxygen are flushed out from the tray and replaced with nitrogen gas (Figure 4.10). The absence of oxygen will reduce the rate of browning and also reatrd microbial growth. In addition, based on the preliminary test by the company with the help of Multivac Sdn Bhd, the shelf-life of the slices can be extended up to 21 days compared to the current method, whereby the shelf-life is about 5 to 10 days depending on hygiene practice of the workers. The trays are then sealed with polyethylene (PE) web. Seal bar cleanliness, temperature and dwell time must all be carefully controlled and monitored to assure proper seals are being consistently produced. As part of a good manufacturing practice all fresh-cut products should be screened for the presence of extraneous ferrous and non-ferrous metal fragments with a metal detectors. An online metal detector can be installed as trays are conveyed to boxing room, whereby the equipment is equipped with automatic ejection device. This MAP process is considered as critical control point (CCP) to ensure that the gas mixture is correct and the package is not leaking.

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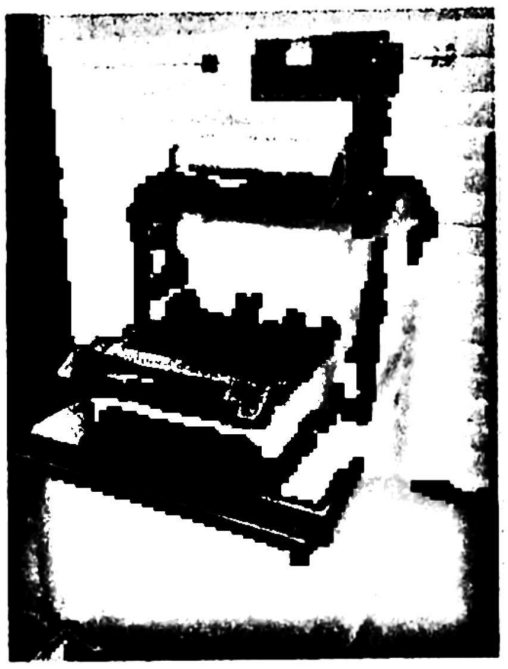

Figure 4.10. Modified atmosphere packaging

9) Boxing and storage

All the trays are packed in the ice box that can bear 10 to 14 kg finished products. The ice box are kept in cold room maintained at 4°C as this is one of the critical control point (CCP) to control and retard the microbial growth in the product. Boxes should always carry a date of manufacture or use by date and production code to allow first in first out product rotation and possibility of product recall. The ice boxes are delivered to the franchises and retailer in a refrigerated vehicle for long distance.

Based on the market survey with the company, it is difficult to find machines that is dedicated for processing yam bean fresh cut. Some of the similar production lines are customised for potatoes, apples and carrots. Nevertheless, there are sections in the line that is not fit for yam bean. As an example, the available slicing machine is not able to cut the yam bean due to small radius of the rotary knife blade compared to average yam bean size with diameter reaching 12 to 16 cm. In addition, yam bean has an oval shape with elongated top and bottom that need to be trimmed. It is therefore proposed that a customized processing line is developed, which can be continuous or batchwise. The development of this equipment is however not include in this project but will be proceeded for the future work.

4.2.3.2 Process Description for the Production of Sauces

The processing of the red sauces and soy-based sauce begins with the receiving of incoming materials, ambient storage, cool refrigerator storage, packaging material

storage in separate location, preparation and weighing, cooking, hot filling, sealing, cooling, labeling, date coding, room temperature storage, shipping. The process flow are given in Figure 4.11 and Figure 4.12.

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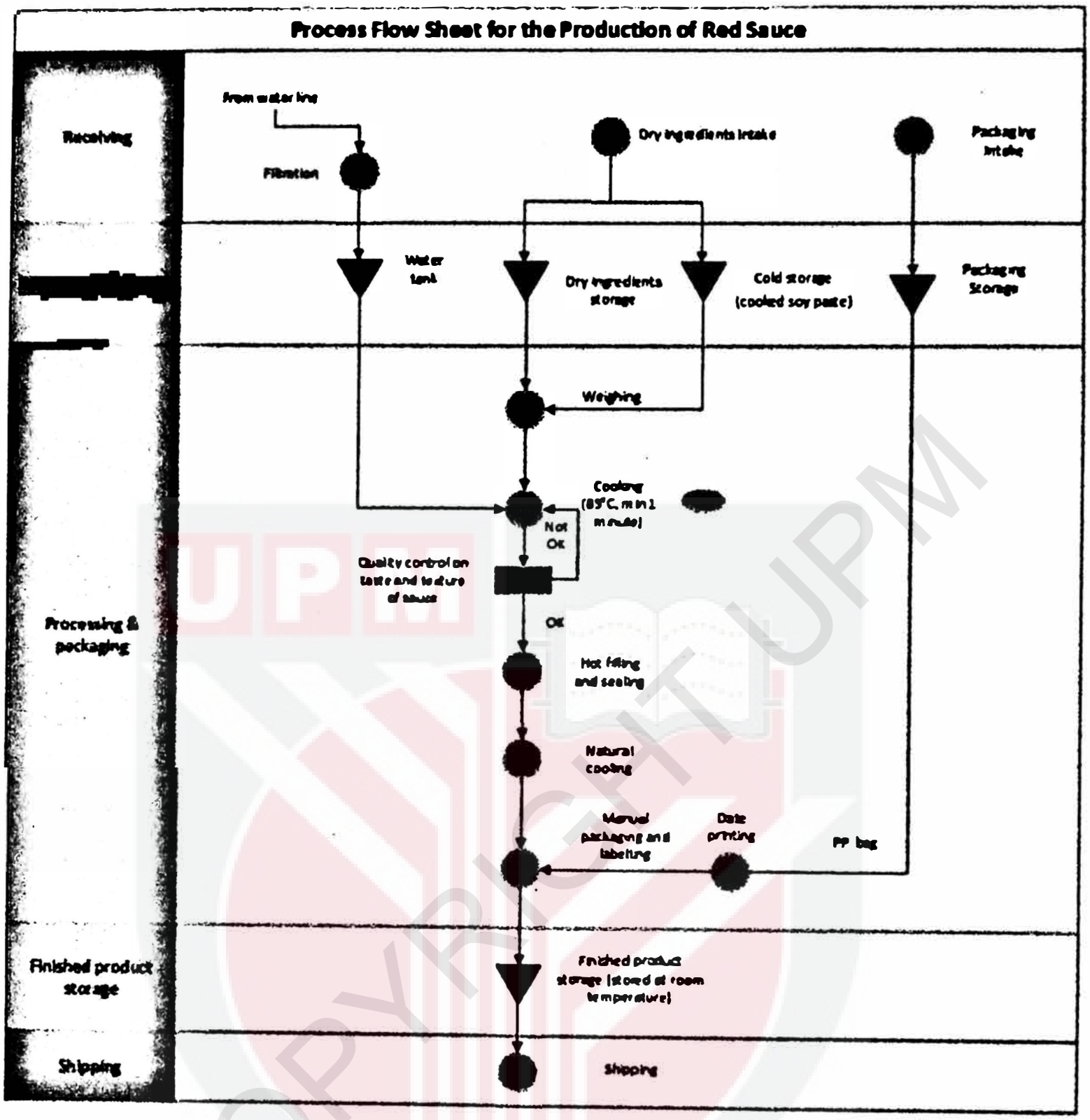

Figure 4.11. Production of red sauce

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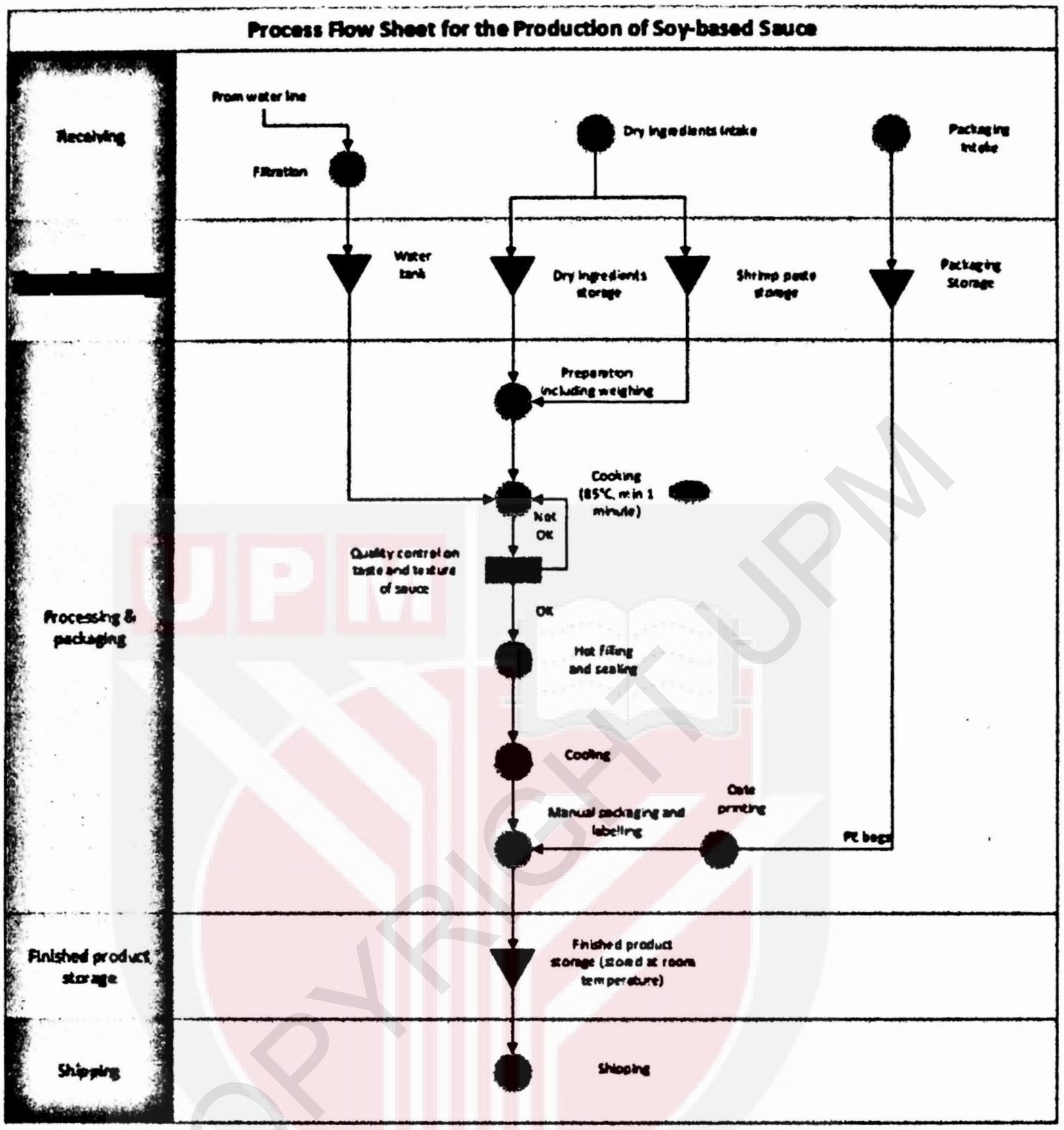

Figure 4.12. Production of soy-based sauce

1) Receiving of incoming raw material

Raw materials are categorized into 3 types: chill, dry and packing materials. The chilled ingredients is for example soy paste, while the dry ingredient are salt, sugar, sweet potatoes and so forth. All the ingredient for sauces is accommodated in a storage room either on shelves or refrigerator. The packing materials are stored in the dedicated packing storage and they are polyethylene bags and cartons.

All incoming materials need to go through organoleptic examination (appearance, smell, any defects or abnormalities). This is to check for any physical damage to the raw material and also evidence of rodent or pest. There would be also specification

check such as date of receipt, name of product, batch number, weigh and quantity received against document and name of supplier. All supplied material need to pass through quality assurance system through random sampling, whereby defected materials are returned.

A separate SOP for detailed on-site quality control is recommended to be developed. Any raw materials not meeting the required specifications shall be returned to the supplier immediately and not allowed to enter the storage.

2) Storage

Upon satisfying the required quality, all the materials were taken to their respective storage room i.e. the chilled food go to refrigerator, the dry ingredients to dry storage, and the pack material to packing material storage. The transports of raw materials can be assisted using the platform trolleys and hand trucks. The weighing station is also accommodate here for the small ingredients (Figure 4.13).

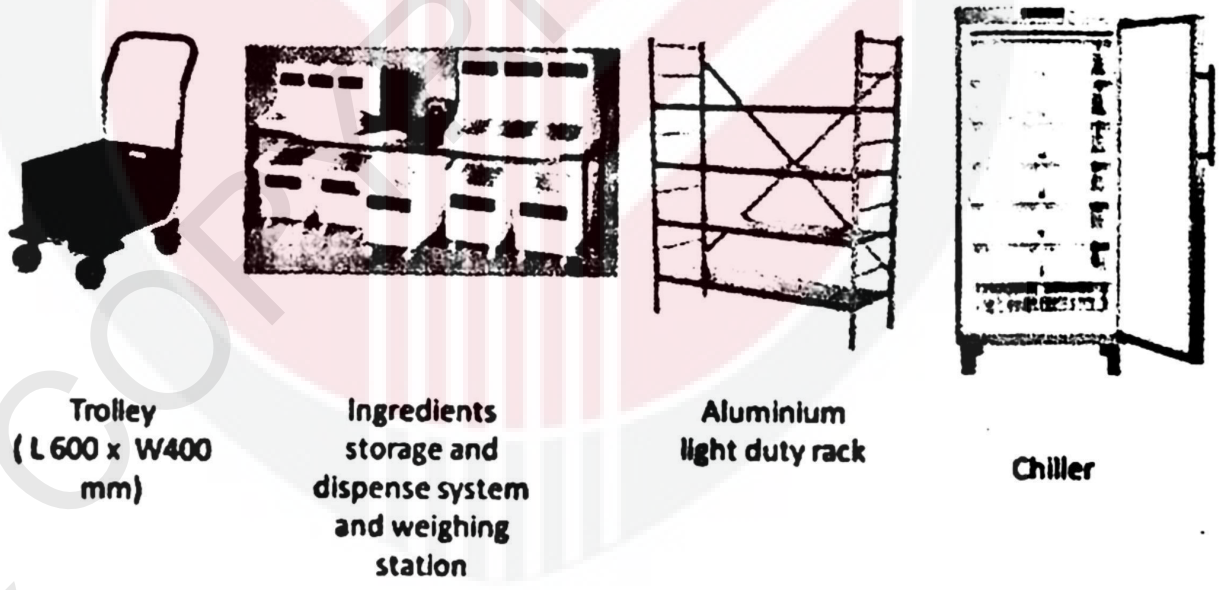

Figure 4.13. Storage equipment (SYSPAL, 2016)

3) Preparation and cooking

All the ingredients are prepared such as washing, grinding and cutting are performed. The washing is done in a wash room while other preparation steps are carried out in cooking room. All the ingredients will be mixed, braised and cooked to make a batch of 24 kg sauces in an automated braising kettle (Figure 4.14). The internal temperature of the sauce must be cooked to at least 85°C for a minimum of 1 minute to retard possible *Salmonella spp., Escherichia coli O157:H7, Listeria monocytogenes and*

Clostridium botulinum. Hence, cooking is a critical control point (CCP) for the HACCP system. The mixing process can be programed to assist the worker and the temperature is electronically controlled with two probes (first inside the pan while second probe measures temperature of food). The braising and cooking use direct heat without jacket. The mixer speed can be regulated and set in both direction, while the pan can be tilted to ease the sauce unloading and cleaning process.

Figure 4.14: Cooking equipment (Firex, 2019)

4) Hot filling and sealing

After cooking, the sauce is waited to cool until 75°C before being unloaded and packed into 1 kg aluminium backplated PE bag. The bag is properly sealed and let cool until ambient temperature.

5) Labelling, date coding and storage

The packed products are labelled important information such as production code, expiry dates and safe-handling instruction. Usually the labels are printed first before attached to the packaging. All the finished products are stored in crate and sent to the ambient storage since the product are commercial sterile.

4.2.3.3 Process Description for the Production of Roasted Nuts

The processing of the roasted nuts begins with the receiving of incoming materials, ambient storage, packaging material storage in separate location, preparation and weighing, roasting, natural cooling, manual packing and sealing , labeling, date coding, room temperature storage and shipping. The process flow is given in Figure 4.15.

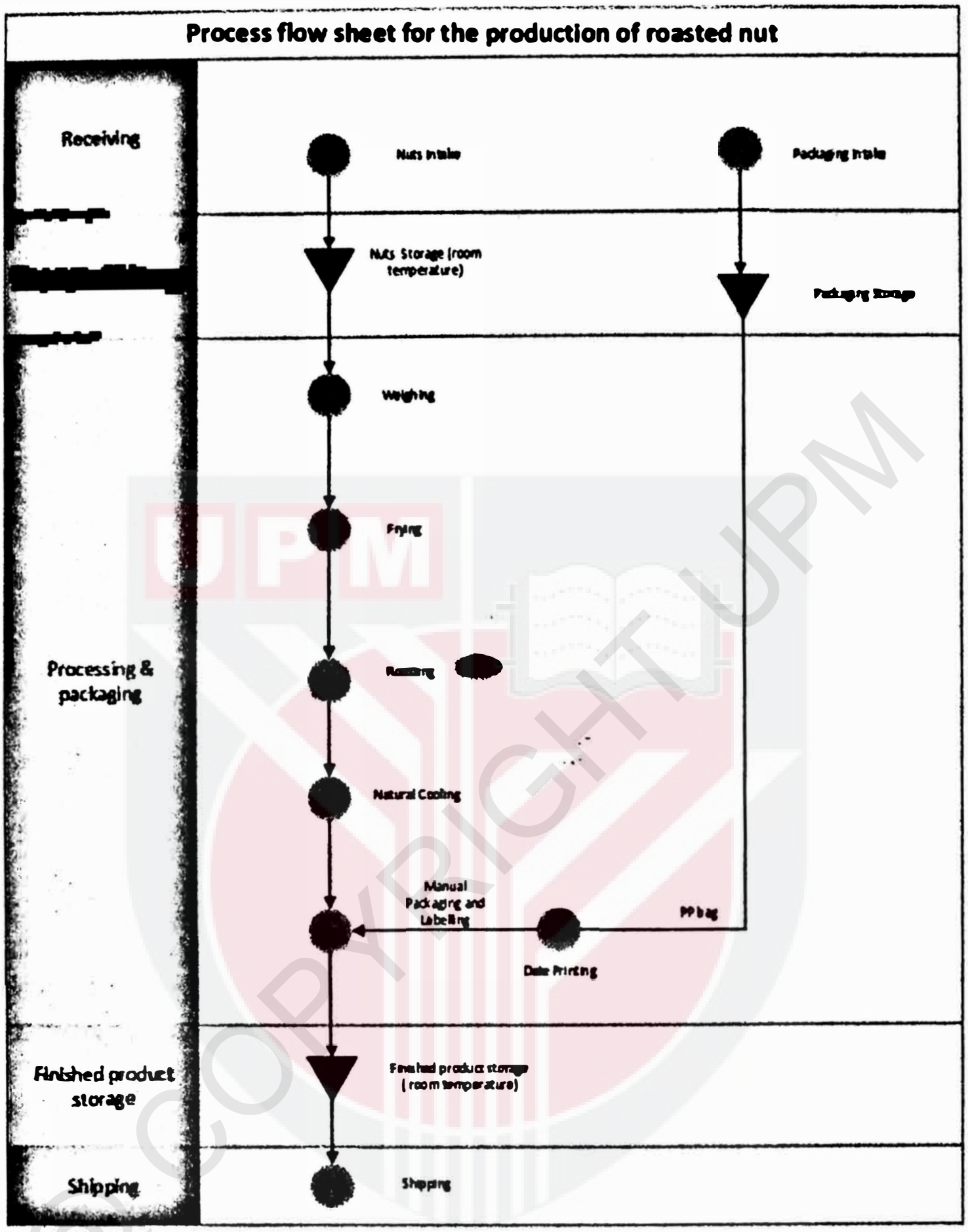

Figure 4.15. Production of roasted nuts

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Basically, the procedure for the receiving incoming materials and storage of roasted nuts are similar to red sauce and soy-based sauce product.

1) Preparation and weighing

The nuts received from the supplier are already grinded and can just weighed to make a batch of 24 kg roasted nuts. The weighing process until packing process is done in the nut production room.

2) Roasting

The temperature of the nuts roasting must be at least 127°C for a minimum of 1.6 minutes to retard possible *Salmonella spp.* (Nut Safety Handbook, 2010). It is important to have this thermal process as a control measure to control this hazard. Hence, roasting is a critical control point (CCP) for the HACCP system. The nuts will be roasted for 10 to 20 minutes in a roasting equipment as in Figure 4.16 (WH Food , 2019).

Figure 4.16: Roasting equipment (Chike Machinery, 2019)

3) Manual packing and sealing

After roasting, the nuts are waited for natural cooling cool before being unloaded and packed into 1 kg aluminium backplated PE bag. The bag is properly sealed and let cool until ambient temperature.

4) Labelling, date coding and storage

The packed products are labelled important information such as production code, expiry dates and safe-handling instruction. Usually the labels are printed first before

attached to the packaging. All the finished products are stored in crate and sent to the ambient storage.

4.2.4 Design Stage 4: Machine List

The main output of this step is the Machine List as shown in Table 4.9 that contains information on the major machining equipment. The major machine types for the sliced yam bean are abrasive peeler integrated with spray wash, sorting conveyor, slicing machine, spray wash conveyor, dewatering blower, modified atmosphere packaging (MAP) machine and metal detector. As for the sauces, the major equipment is the automated braising and cooking kettle while for the nuts, the equipment is the roasting oven. Other minor equipment are, for example, electronic scale, platform scale, date printer machine and packing sealer are not included in the Machine List.

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Table 4.9. Machine List

Machine code	Machine description	Model	Size (LxWxH) and space req.	Number of units	Capacity performance	Utility requirement
			Production Line For Sliced Yam Bean			
M1	Abrasive peeler and spray wash	MSTP-500	1000 x 600 x 1050 A =0.6 m^2	1	100 kg/batch	P = 1.5 kW
M2	Sorting conveyor	JM-WSC	2900 x 500 x 1050 A = 0.5 m^2	1	100 kg/batch	P = 1.5 kW
M3	Slicing machine	BY-WQC60	500 x 800 x 1050 A= 0.4 m^2	1	100 kg/batch	P = 0.75 kW
M4	Spray wash conveyor	RH-3500	1400 x 600 x 1050 A= 0.84 m^2	1	100 kg/batch	P = 4.75 kW
M5	Dewatering blower	DM-50	1000 x 500 x 1050 A= 0.5 m^2	1	100 kg/batch	P = 0.75 kW
M6	Modified Atmosphere Packaging (MAP) machine	T200	1460 x 781 x 1629 A= 1.14 m^2	1	160 tray/batch	P=1.5 kW E= 220 V / 50 Hz
M7	Metal detector	WILPAC WP-G5020	Can be integrated into conveyor	1	Adjustable up to 24 m/min =800 packs /min	*P= 0.1 kW* *E= 230 V* */50 Hz /1 Ø*

Table 4.9 continued.

			Production Line For Sauces			
M-8	Automated braising and cooking kettle	CBTE03 0 V1	880 x 766 x 970 A= 0.68 m^2	1	30 L/batch	*P*=6.2 kW E= 380 V / 50 Hz
			Production Line For Roasted Nut			
M-9	Roasting oven	DCCZ 3-4	750 x 520 x 800 A= 0.39 m^2	1	30 kg/batch	*P*= 0.6 kW E= 220 V
			Miscellaneous			
M-10	Date printer machine	Uniq	286 x 283 x196	1	80 times/min	P = 0.06 W E- 220 V

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4.2.5 Design Stage 5: Facilities Design

The main outputs of this stage are the Room List and Room Design Data Sheet. The Room List provides all the processing room that should be made available in this factory and is given in Table 4.10.

Table 4.10. Room List

Storage	Production	Transition
Yam bean storage room	Yam bean production room (low-risk)	Receiving facility
Sauce ingredients storage room	Sauce production room (low-risk)	
Nuts storage room	Nuts production room (low-risk)	
Packaging material store (PP tray, PE bag , ice box and labels)	Yam bean packing room (high-risk)	Shipping facility
	Sauce packing room (high-risk)	
Yam bean finished product room	Nuts packing room (high-risk)	
Sauce finished product room		
Nuts finished product room		

Every room must be provided with Room Design Data Sheet in which this section demonstrates the Room Design Data Sheet for yam bean production room and for yam bean storage.

4.2.5.1 Design of Yam Bean Room (Storage)

The data sheet as shown in Table 4.11 contains design details for the yam bean storage room. Section A lists down the equipment in the room that has been determined at Process Specification (at Design Stage 3). Section B set the condition such as low-risk zone, room temperature of 20°C and so on. Section C list down the utility that need to be provided. Section D records the structure of the room, while Section E presents the schematic layout of the room.

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Table 4.11. Example of Room Design Data Sheet developed for the yam bean storage

UPM	ROOM DATA SHEET			NEW FACTORY X			
Document name :		Author:		Date:	Version:		
Room Data Sheet for Yam Bean Storage Room		Nurulnadiah Johari		17.3.2019	Draft		
Building:	New Factory X		Room number:	YBS01			
Room :	Yam bean storage room		Level:	Ground floor			
Project Nr:		1					
Room function:		To store raw yam bean received from supplier at room temperature					
Occupancy:		Person	full shift		Area:	12.96	m²
	2	Person	minimum	3 h/d	Height:	3	m
Working hours:	9	hours			Volume:	38.88	m³
A. Equipment							
1	Platform trolley x 1 unit						
2	Rack x 2 unit						
B. Room Condition							
1	Zone:	Low risk (GMP area)					
2	Explosion class:	Not classified					
3	Room temperature:	20°C					
4	Humidity:	70%					
5	Ventilation:	No					
6	Air change:	2 air change/d					

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Table 4.11 continued.

C. Room Utilities		
1	Water	Not required
2	Wash basin, rinse or sanitary equipment	Not required
3	Floor drainage	Not required
4	Compressed air	Not required
5	Steam and condensate	Not required
6	Gas	Not required
7	Liquid	Not required
8	Vacuum	Not required
9	Electrical power supply	Required
10	Emergency power supply	Not required
11	Lighting	110 Lux , fluorescent T8 lamp, protected in sleeves cover
12	Telephone	Not required
13	Data communication	Hand-record
14	Other communication equipment	Not required
15	Smoke detector	Not required
16	Sprinkler	Not required
17	Fire extinguisher	Not required
18	Operators safety equipment	Not required
D. Room structure		
1	Flooring	Epoxy resin
2	Wall	Epoxy resin wall coating
3	Ceiling	Epoxy resin ceiling coating
4	Corner	Coving at floor-wall-ceiling junction with 50 mm radius

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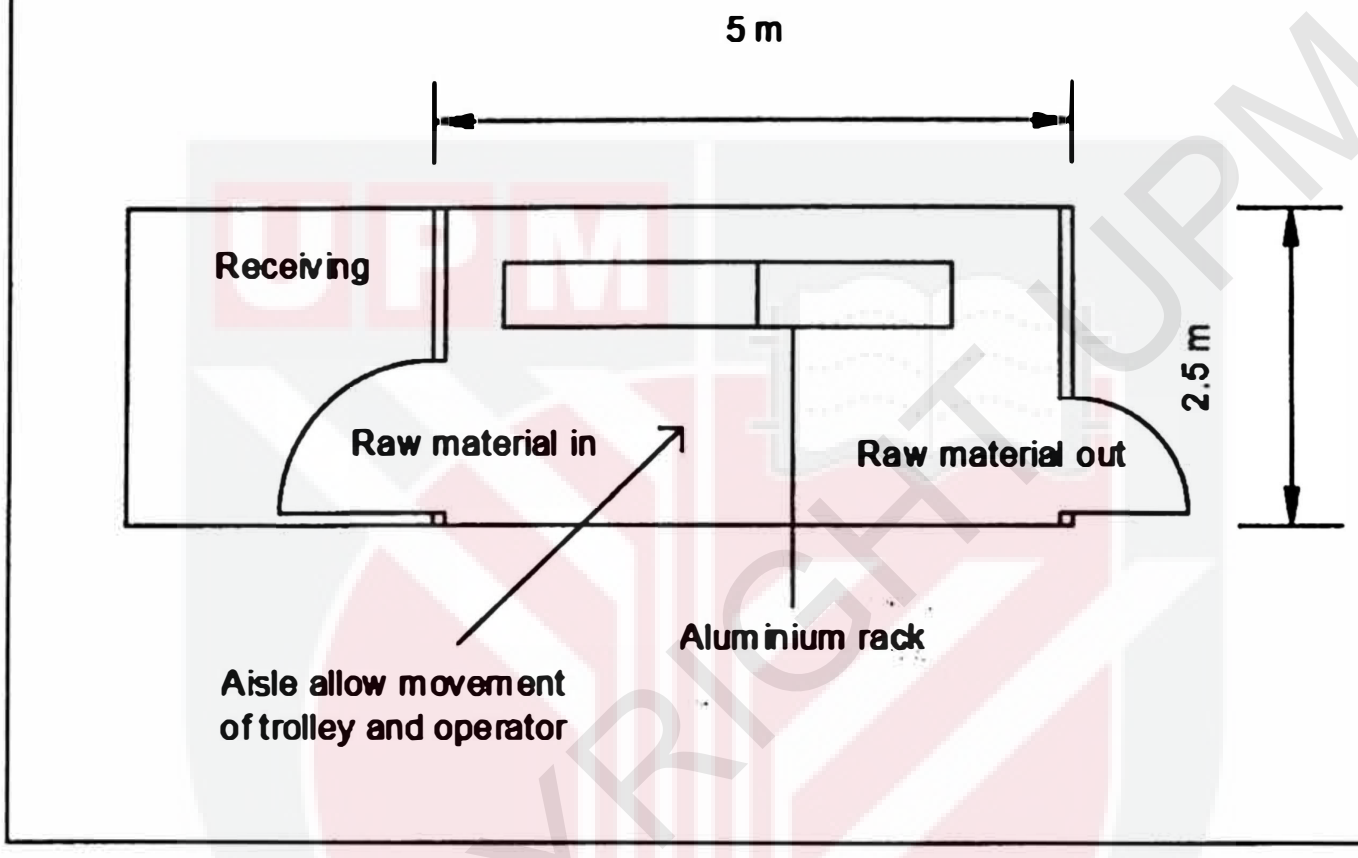
Table 4.11 continued.

5	Door	Stainless steel panel with resin coating
6	External window	Not permitted
7	Internal window	Not permitted
8	Others	Not required
E. Layout		



The layout is developed with the raw materials to be stored in 2 units of aluminium racks . The aluminium rack had a standard size of 2000 mm x 500 mm x 2800 mm and 1500 mm x 500 mm x 2800 mm, static load capacity of 1500 kg and can be loaded up to 2600 mm height. In average, one aluminium rack is able to accommodate 12 to 18 crates (240 to 360 kg) and can be stacked up to 5 or 6 crates .This gives out 2 aluminium rack footprints arranged in one row. The clearance between aluminium racks to the wall is 450 mm for inspection and cleaning (hygiene). All the crates will be moved using trolley of size 600 mm x 500 mm x 1000 mm. Hence, the width of aisle is dimensioned about 1500

mm as width of aisle = 500 mm + width of trolley + 500 mm (Jung, 2010). The dimension of the room is given as 5 m x 2.5 x 3.0 m.

4.2.5.2 Design of Low-Risk Production Room

The room design data sheet for the low-risk production room follows the same format as the storage room. This is given in Table 4.12. The production room is identified as the "low-risk" area since the room accommodates the processing activities that take place before the aseptic packing and filling (primary packing).

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Table 4.12. Example of Room Design Data Sheet developed for the yam bean production room

UPM	ROOM DATA SHEET			NEW FACTORY X		
Document name :		Author:		Date:	Version:	
Room Data Sheet for Yam Bean Production Room		Nurulnadiah Johari		17.3.2019	Draft	
Building:	NEW FACTORY X	Room number:		YBP01		
Room :	Yam bean production room	Level:		Ground floor		
Project Nr:	1					
Room function:	To produce fresh-cut yam bean in accordance to product specification					
Occupancy:	Person	full shift		Area:	33	m^2
	3 Person	minimum	1h/d	Height:	3	m
Working hours:	9 hours			Volume:	99	m^3
A. Equipment						
1	Platform trolley x 1 unit					
2	Abrasive peeler and spray wash					
3	Sorting conveyor					
4	Slicing machine					
5	Spray wash conveyor					
6	Dewatering blower					
7	Metal detector					
8	Crate/Bin					
B. Room Condition						
1	Zone:	Low risk (GMP area)				
2	Explosion class:	Not classified				
3	Room temperature:	25°C				
4	Humidity:	70%				
5	Ventilation:	Mechanical (AHU) for GMP area				
6	Air change:	2 air change/d				
7	Air over-/underpressure	Normal pressure				
8	Emission/waste	Water from washdown and solid waste (yam bean peeled skin)				

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Table 4.12 continued.

	C.Room Utilities	
1	Water	Required
2	Wash basin, rinse or sanitary equipment	Not required
3	Floor drainage	2 point gully
4	Compressed air	Not required
5	Steam and condensate	Not required
6	Gas	Not required
7	Liquid	Not required
8	Vacuum	Not required
9	Electrical power supply	Required
10	Emergency power supply	Not required
11	Lighting	110 Lux , fluorescent T8 lamp, protected in sleeves cover
12	Telephone	Not required
13	Data communication	Hand-record
14	Other communication equipment	Not required
15	Smoke detector	Required
16	Sprinkler	Not required
17	Fire extinguisher	1 potable unit
18	Operators safety equipment	Not required
	D. Room structure	
1	Flooring	Resin based flooring material (e poxy)
2	Wall	Polyresin wall
3	Ceiling	Polyresin wall
4	Corner	Fiber reinfored panel with resin based
5	Door	Stainless steel door (Food Grade)
6	External window	Not permitted
7	Internal window	Not openable
8	Others	Not required
	E. Layout	

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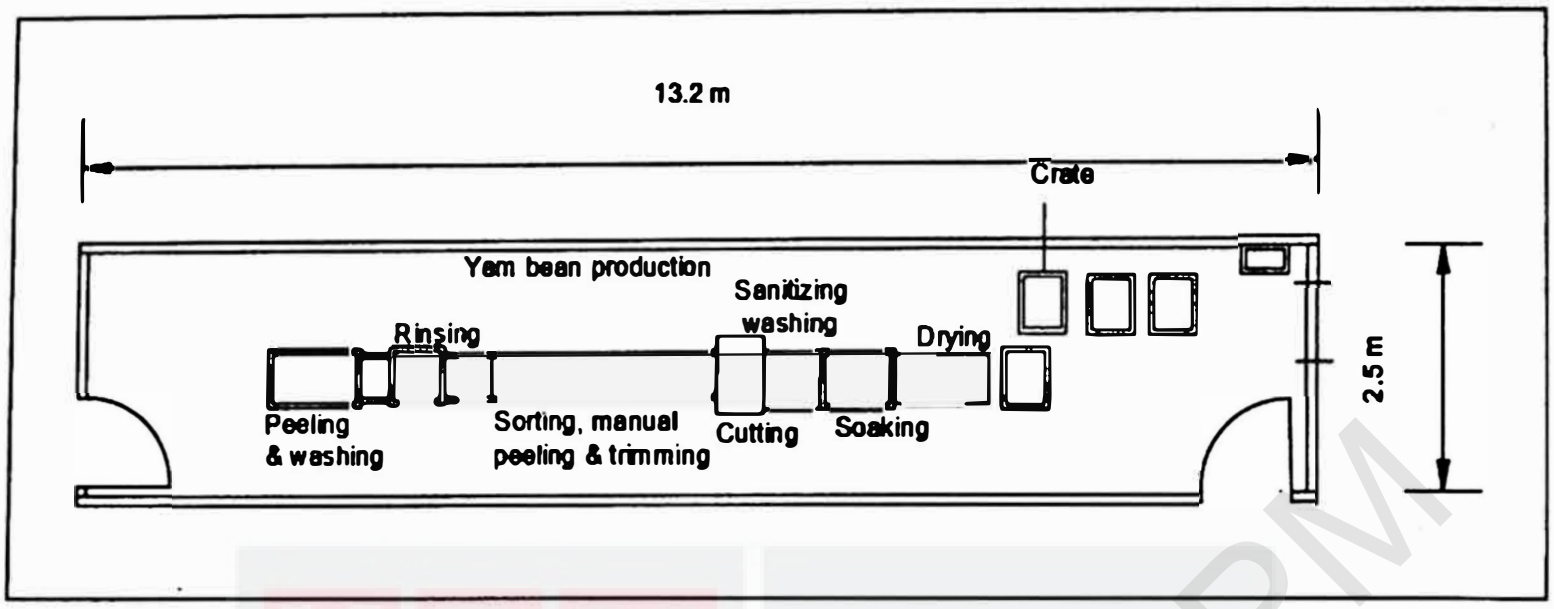
Table 4.12 continued.



The dimension of the room is given as 13.2 m x 2.5 x 3.0 m. The layout ensures the one-way flow production. The layout of the room are developed by combining the seven single workstation layouts (peeling and washing, rinsing, sorting, manual peeling and trimming, cutting, sanitizing washing, soaking and drying). The clearance between machines and adjacent items is minimally 1 m. Objects with purple line are the material handling equipment that would aid the movement of WIP material from one workstation to another. The width of working space for operator is at minimum 1 m (Jung, 2010). The aisle is dimensioned as width of material handling equipment, 2 x 0.5 for equipment movement. The working space of operator must at least has the width between 0.875 to 1 m.

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4.2.6 Design Stage 6: Auxiliary Facilities

The main design output is the auxiliary facilities design requirement. Particular consideration is given for personnel hygiene facilities. As recalled from the Room List in Table 12, there are low-risk production room and high-risk packing room. These called for the need of change rooms and also hand wash station before accessing the production room and packing room. The size of change room is planned to accommodate 3 operator/ change.

The change room and hand-wash station is positioned before accessing the production room and packing room. They are provided in a single cabinet room and should be ventilated with over-pressure to prevent air contaminant from entering the room. A cross-over line is design to separate the low risk side and high risk side of the change room. The size of high-risk change room is planned to accommodate 2 workers/change since only 2 operators are specified for packing task.

Since the company has specified ≥10 workers are to be employed in processing area, separate toilet is required for male and female operators. Each toilet is provided with one lavatory, urinal (for male) and hand-wash basin (UBBL, 1984). The location of toilets must be isolated from the processing area and be barriered by low-risk change room as in Figure 4.17.

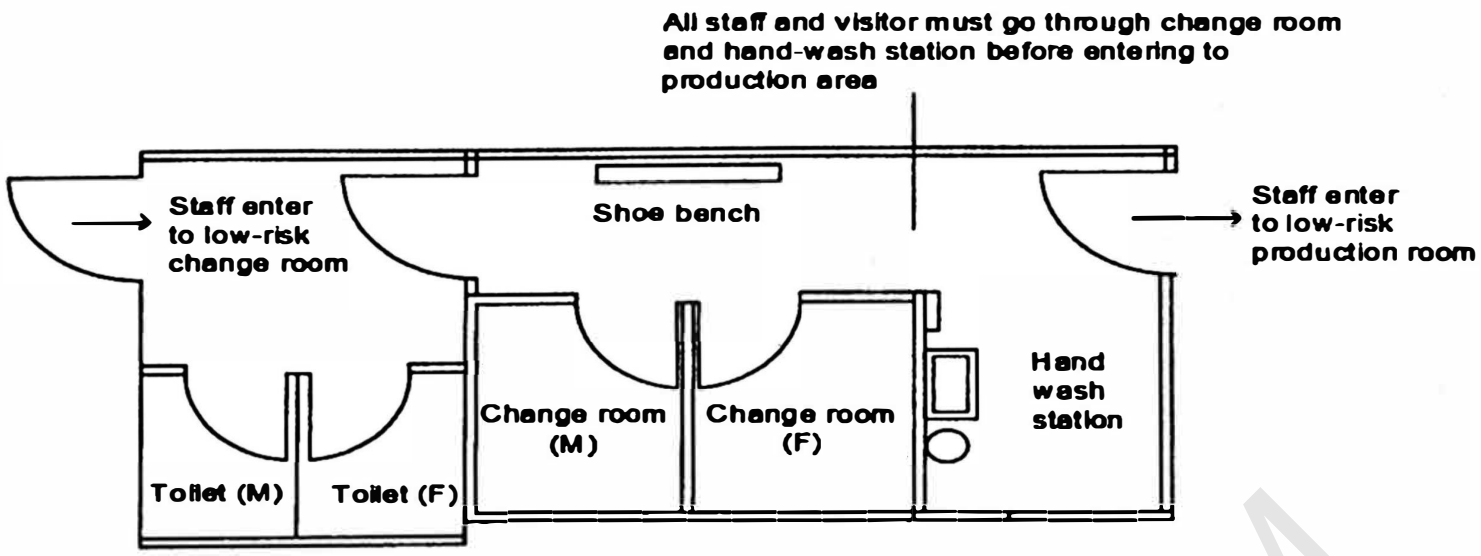

Figure 4.17. Layout developed for low-risk change room, hand wash station and toilet

Other auxiliary facilities that are proposed to be on the same floor as the manufacturing floor are given in Table 4.13. These are office, laboratory, switch room, mechanical room, and janitorial room, chemical store, cleaning room and waste water station .

Other common facilities such as break room, prayer room are not included as these could be located on the second floor of the building and out of this study scope. The laundry facility for boot and factory clothing is excluded and decided to be outsourced due to capital, staffing and space constraint.

Table 4.13. Proposed auxiliary facilities

Facilities	Important design details
Production and inventory office	Design according to a single office format with floor area 8 to 10 m^2. Ventilation rate according to the local guidelines.
Laboratory for QC/QA	The laboratory would have access to low-risk area and provided with hand wash/dry facility. Other compulsory equipment as in Meng et al. (2005) are to be provided. Provision of aisle width at minimum 1.2 m with staff working only on one side of bench (Meng et al., 2005)

Table 4.13 continued.

Switch room	Switch board is to be wall-mounted with front access minimally 4.5 ft. (TNB, 2015). The room is designed to be lockable, has adequate ventilation, installed with anti-vermin netting at any opening. Emergency lighting is required. It is proposed to be located near the main power user in the factory to minimize power loss.
Cleaning room	The room is required to clean utensils and pieces of equipment during production time. The size planned is to accommodate maximum two operators (1.5m^2 /operator with aisle width not less than 0.875 m), wash-sink and space to place the utensils. An exhaust fan is specified to create negative pressure and to exhaust the aerosols. Floor sloping is required heading towards floor drainage (equipped with fat trap) and then proceed to wastewater treatment facility
Storage for cleaning tool and chemical	The room is to store detergent, disinfectant and also tools for cleaning. No hazardous chemical is expected. The size planned for the room is to accommodate lockable storage shelve, storage box for cleaning tool and aisle width at least 0.875 m. The room itself must be lockable and secured.
Waste station (for solid and effluent)	The waste water treatment as well as dumpster are positioned outside the manufacturing premise in an open-air environment. The waste dumpster is provided lockable enclosure. Water source and drainage are required for cleaning.
Water treatment station	A station for small unit of commercial water treatment process with estimated footprint of 1 m^2 is required near the main water supply pipeline. The station must be secured from unauthorized access

The finishing structure of all facilities above do not need to be of food-grade materials except for cleaning room and laboratory, in which the structure such as flooring, wall and ceiling followed the GMP-area specification.

4.2.7 Design Stage 7: Space and Workforce Program

The main outputs at this stage are Workforce and Space Program. The Workforce Program is given in Table 4.14 with only one working shift/day of 9 hours is specified by the company.

Table 4.14. Workforce Program

Department	Job scope/task (*i*)	Manpower requirement	Time load/manpower
Management	Director	1	8 h/d
	Secretary	1	8 h/d
Administrative	General administration	1	8 h/d
	Sales and marketing	1	8 h/d
	Finance and accounting	1	8 h/d
	Purchasing	1	8 h/d
Production operation	Production management and planning	1	8 h/d
	Store control	2	1-2 h/d
	Receiving and shipping	2	1-2 h/d
	Production	2	7 h/d
	Packaging	2	4 h/d
	Boxing	2	2 h/d
Quality assurance and control	Raw material inspection, in-line processing, storage, quality control and analysis ,HACCP and GMP	1	8 h/d
Engineering and Maintenance	Machineries, building and infrastructure maintenance and checking, repair	1	8 h/d
Cleaning (non-production)	Cleaning	1	4 h/d
Logistic (Driver)	Shipping	1	8h/d

Since Company X had capital constraints in hiring, the number of staff (N_{staff}) can be minimized by maximizing the utilization of working time. For example, the operators working in the raw material storage can also be working in the finished product storages as their time load is only about 1 to 2 h/d.

The Space Program is given in Table 4.15. The total floor area required to build the facilities are 189.57 m^2, which is about 70 % of the available floor area in the building. The remaining 30 % may be useful for other spaces such as aisles between or safety factor for the complete building layout.

Table 4.15. Space Program

Department	Room name	Room code	Length (m)	Width (m)	Area (m^2)
Processing	Yam bean production room	YBP01	13.20	2.50	33.00
	Sauce production room	SP01	3.10	2.50	7.75
	Nuts production room	NP01	3.10	2.50	7.75
	Yam bean packing room	YBP02	5.40	2.50	13.5
	Sauce packing room	SP02	2.70	2.50	6.75
	Nuts packing room	NP02	2.70	2.50	6.75
	Yam bean storage room	YBS01	4.80	2.50	12.00
	Sauce ingredients storage room	SS01	4.00	2.50	10.00
	Nuts storage room	NS01	2.00	2.50	5.00
	Packaging material storage room	PM01	3.50	2.50	8.75
	Yam bean finished product storage	YBFP	4.50	2.50	11.25
	Sauce finished product storage	SFP	3.00	2.50	7.50
	Nuts finished product storage	NFP	3.00	2.50	7.50
	Receiving area	RA01	2.00	2.50	5.00
	Shipping area (outside aisle)	SA01	1.50	2.50	3.75
Auxiliary facilities	Chemical room	CR01	1.80	1.20	2.16
	Laboratory	LAB01	2.08	2.80	5.82
	Tool room	TR01	3.07	1.41	4.33
	Switch room	SW01	1.75	1.41	2.47
	Cleaning room	CL01	1.80	1.96	3.53
	Waste water treatment station	WWT	2.73	1.96	5.35
	Toilet (F)	TF01	1.38	2.19	3.02
	Toilet (M)	TM01	1.38	2.19	3.02
	Change room(F)	CHRF01	1.95	2.19	4.27
	Change room (M)	CHRM01	1.95	2.19	4.27
	Hand wash station	HW01	1.75	2.90	5.08
	Total floor area required (m^2)				189.57

4.2.8 Design Stage 8: Layout Design

The main design output at this stage is the plant layout.

4.2.8.1 Factory Layout

The New Factory X is shown in Figure 4.18. The layout shows the spine aisle as the central core for the production traffic. Four major functions can be seen in the layout namely low-risk, high-risk, transitional area and auxiliaries.

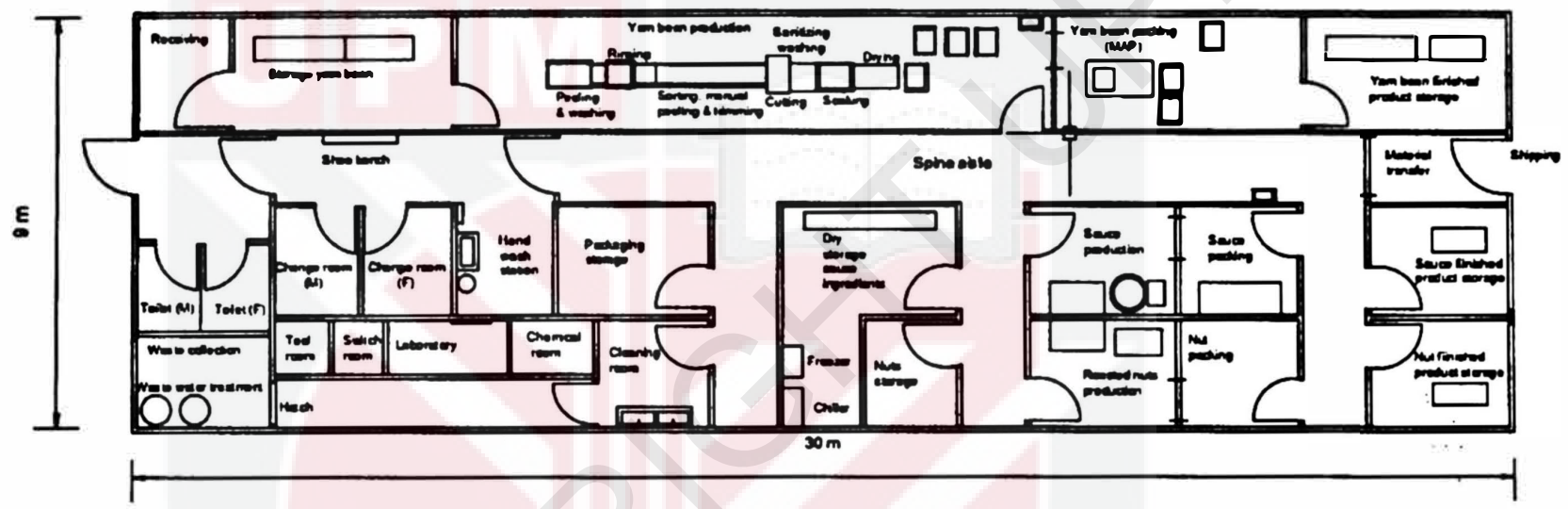

Figure 4.18. Schematic plant layout proposal for new Factory X

As referred to Figure 4.18, the food material is received in the receiving area at the western side of the premise. The incoming material then proceed to the respective storage which are yam bean storage, dry ingredients storage of sauce , nuts storage and packaging storage via the spine aisle. During the production, the food materials is brought to their respective workstation in production room or the packing area where major machines are located.

At the end of the end of the production line, the products formed are then packed according to their packaging type in the high-risk packing room .The finished products in crates are sent to the storage room according to their product and ready to be shipped. The schematic layout shows no criss-cross and backtracking in the material movement and thus, reduce the cross-contamination. The transfer hatch is provided to allow waste

transfer to the outside , without the operators having to exit the factory. This is important to prevent the cross-contamination.

4.3 Design Analysis

This section presents the design analysis to evaluate the effectiveness of the New Factory X design in improving the productivity and delivering the hygienic condition for the factory. A comparison analysis using actual buildings is desirable (Rani et al., 2014). However, such evaluation method would require the new building design to be constructed and compared to the current premise. This would involve administrative, authority approval, fund allocation, construction and commissioning which are not within the capability of this study (Darmawan, 2002). Therefore, the analyses in this section were carried out using simulation analysis for the productivity using FlexSim and hygienic design scoring . Economic analysis was also carried out to evaluate the Return On Investment (ROI) and payback period of the newly designed factory.

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4.3.1 Simulation Analysis

Simulation analysis is used to analyse productivity and production lead time during the factory operates. The results are discussed in related to operator's utilization, processor's utilization and stay time of product at workstation. Simulation analysis shows that the productivity performance are obtained as Table 4.16 below.

Table 4.16. Productivity performance of current premise and New Factory X.

Analysis	Current premise				New Factory X			
	Yam bean	Red sauce	Soy-based sauce	Roasted Nut	Yam bean	Red sauce	Soy-based sauce	Roasted Nut
Productivity (kg/h)	7	0.5	0.5	8	18	5.5	5.5	24
Production lead time (h)	5.4	22	2.2	3	4.5	22	2.2	1

Based on Figure 4.19 below, the productivity of yam bean product, sauces and roasted nut in the New Factory X increases as much as 2.6, 11 and 3 times respectively compared to the current premise. Meanwhile, the production lead time of yam bean product, sauces and roasted nut in the New Factory are reduced about 17%, 90% and 67% respectively compared to the production lead time in the current premises as shown in Figure 4.20 below.

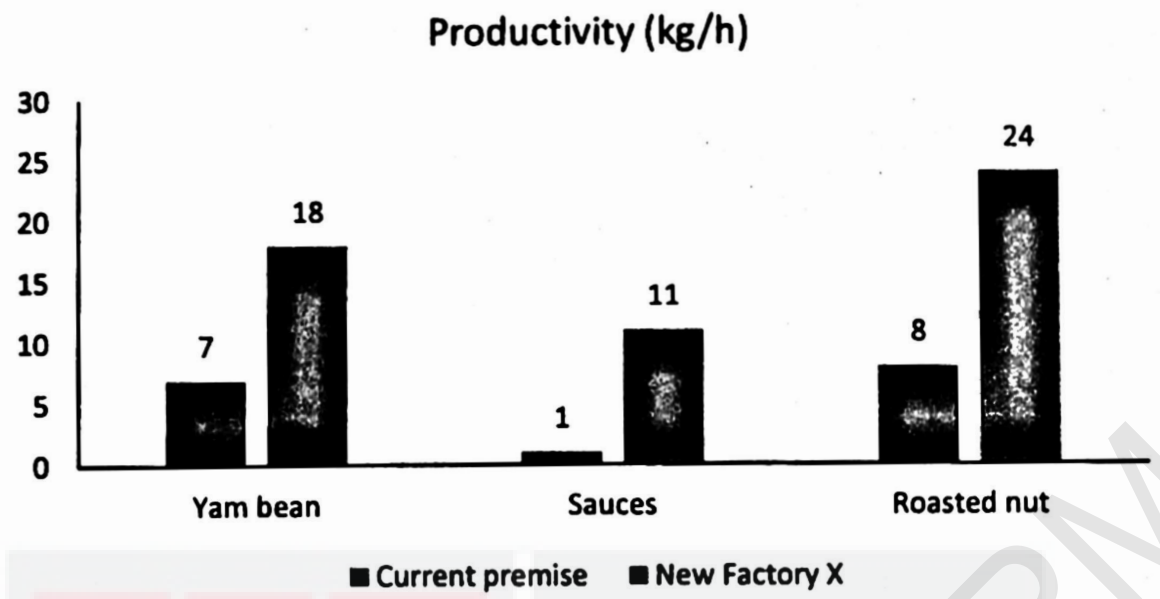

Figure 4.19. Productivity improvement analysis

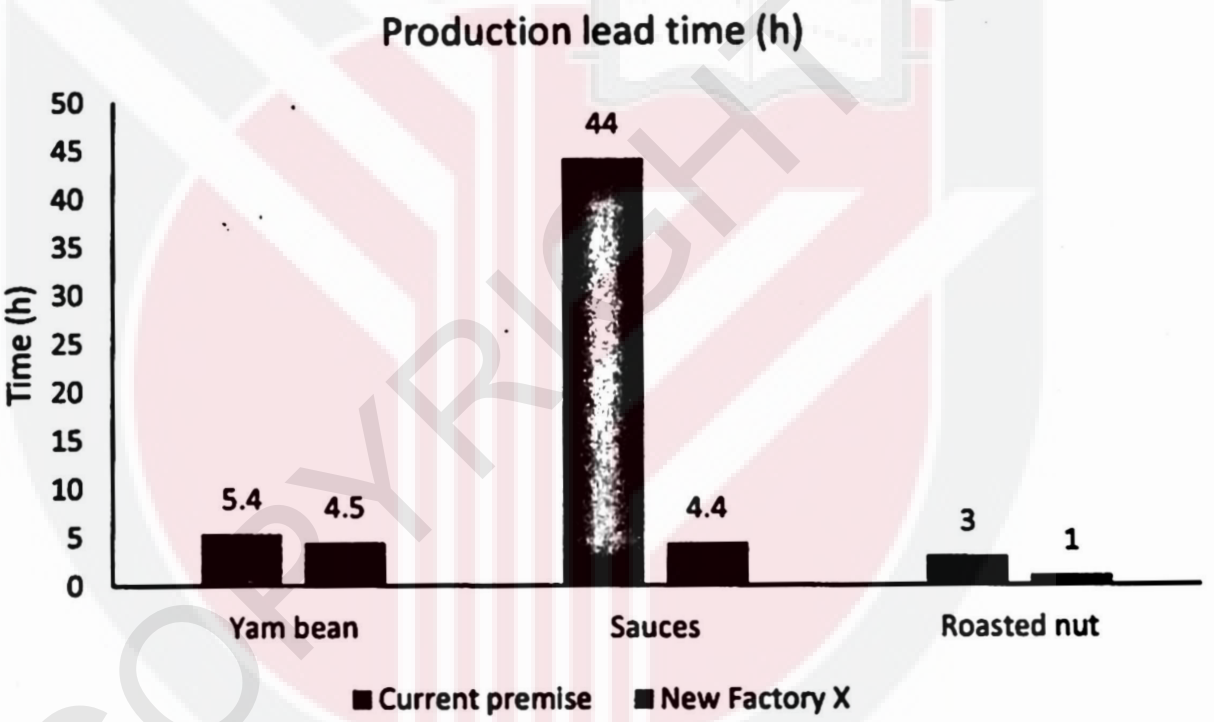

Figure 4.20. Production lead time analysis

Low productivity and long production lead time of the products in current premise can be sourced back from inefficient process workflow which used mostly manual and manpower for major process in the production line. As example, for yam bean product, the most crucial process is the slicing of yam bean. In current premise, only one person can slice the yam bean according to the correct specification especially the standard size of the yam bean. Hence, too much time spend in slicing the yam bean which is about 5.4 hrs per

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batch. The limited manpower for slicing results in low productivity and long production lead time for the yam bean product. This can be referred to the simulation results for current premise in Figure 4.21(a) where it shows Operator 2 utilizes most of the time to do the slicing process since he is the only one that has the skill for the slicing task compared to the other 3 operators. The slicing task required consistency as low as 1 cm per slice and the task can be hazardous due to finger-cut risk as the tubers are slippery. Figure 4.21(c) shows that for the processor's utilization, slicing station has the highest percentage of time utilization due to the slicing process (59%) while Figure 4.21(e) clearly shows that slicing station has the highest average staytime of yam bean followed by washing since the next bucket of yam bean has to queue before being processed by the slicing station.

For the New Factory X, the productivity is higher and has shorter production lead time due to efficient process workflow which used semi-automatic and fully automatic machine in the production line. As example, for yam bean production line, the process flow has been modified and the machines are customized according to the desired capacity of the product. Therefore, semi and fully automation of the yam bean processing line results in higher productivity (increased 2.6 times) and shorter production lead time of the yam bean product (decreased 17%). This can be referred to the simulation results for New Factory X in Figure 4.21(b) that shows the division of the operator's work task is balanced and more systematic than current premise. Figure 4.21(d) shows that for the processor's utilization, slicing station has the highest percentage of time utilization due to the slicing process that uses the customized machine while Figure 4.21(f) clearly shows that slicing

station has the highest average staytime of yam bean since the slicing machine need more time to complete the process compared to other machine.

As for the sauces, the reduction in lead time and the increase in productivity was mainly due to the high capacity of FIREX cooking machine which is 30 kg per loading and therefore, able to yield 24 finished packs per batch. This implied that the cooking time for 24 kg sauces was reduced about 90 % as can be observed in Figure 4.22(c) and 4.22(d). Similar observation can be obtained for the roasted nuts, whereby the reduction in lead time and the increase in productivity was mainly due to the roasting nut machine that is able to roast 30 kg per loading and hence, able to produce 24 finished packs per batch. This implied that the cooking time for 24 kg roasted nuts was reduced about 67 % as can be observed in Figure 4.23(c) and Figure 4.23(d).

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Current premise	New Factory X

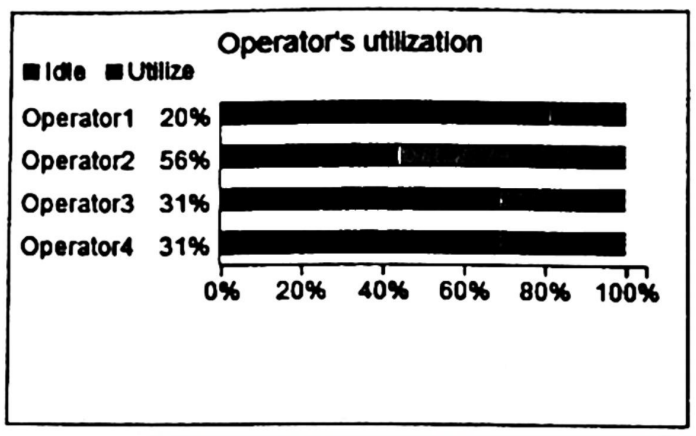
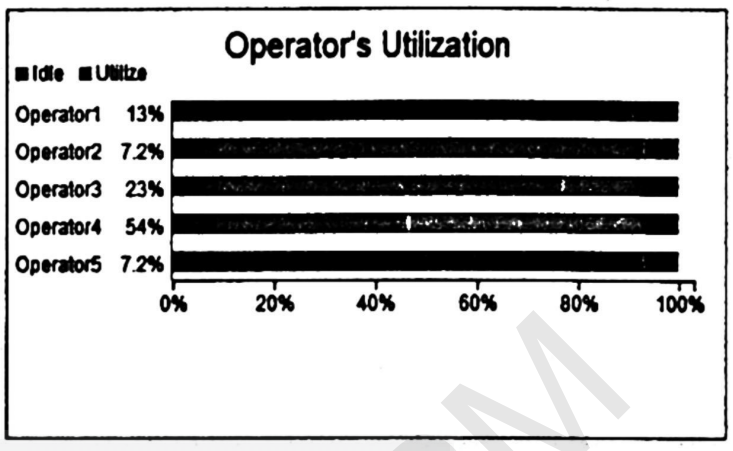

	

Figure 4.21(a)	Figure 4.21(b)

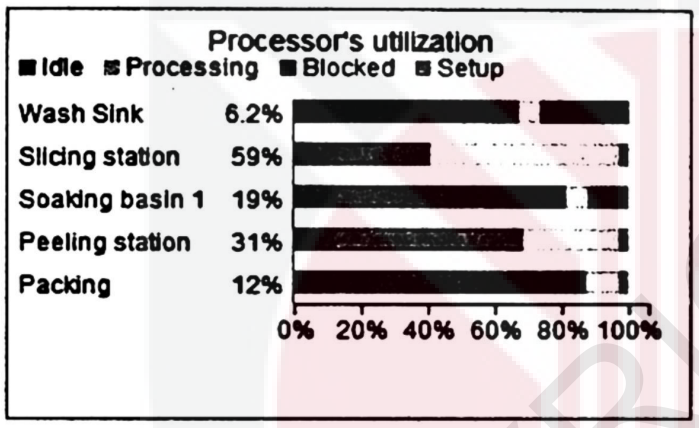
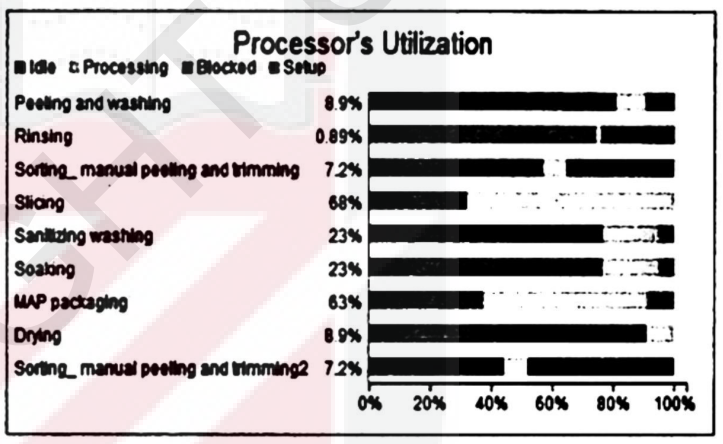

	

Figure 4.21(c)	Figure 4.21(d)

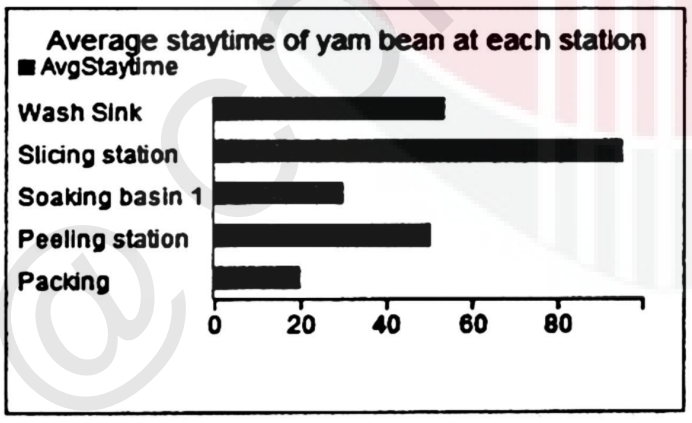
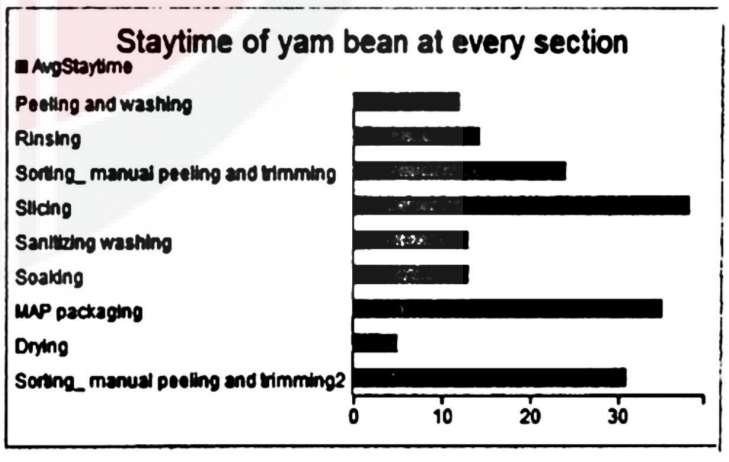
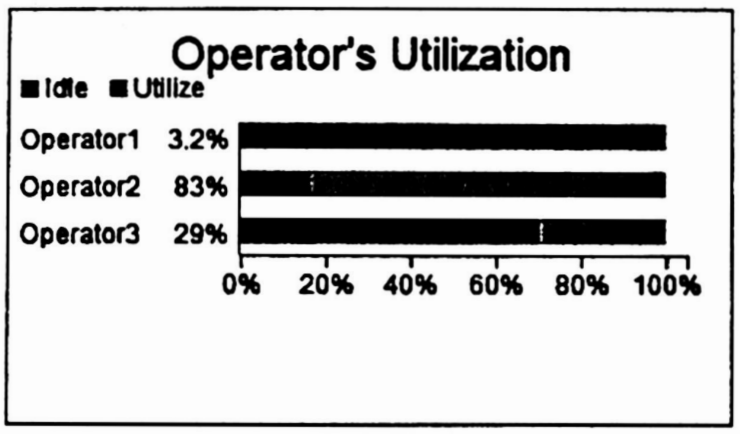
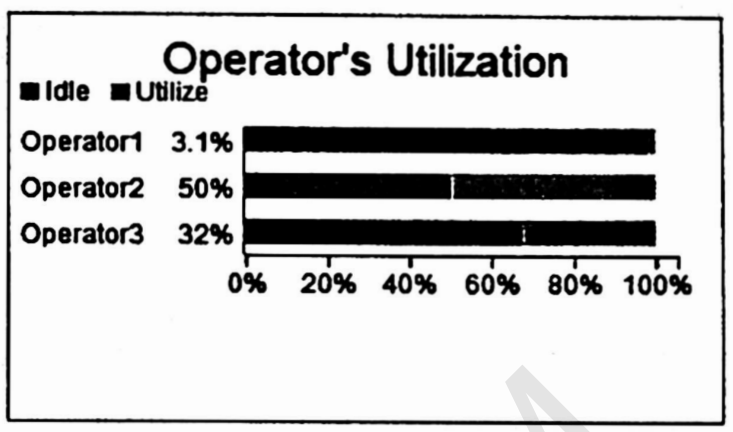

	

Figure 4.21(e)	Figure 4.21(f)

Figure 4.21. Simulation results of yam bean products for current premise and New Factory X

Current premise	New Factory X
	
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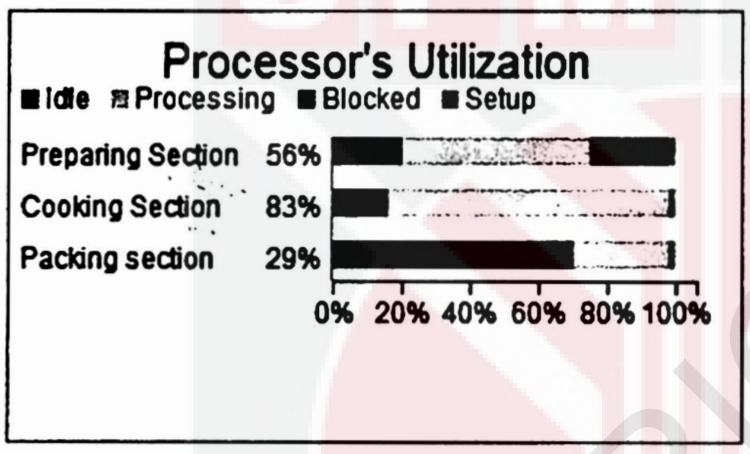	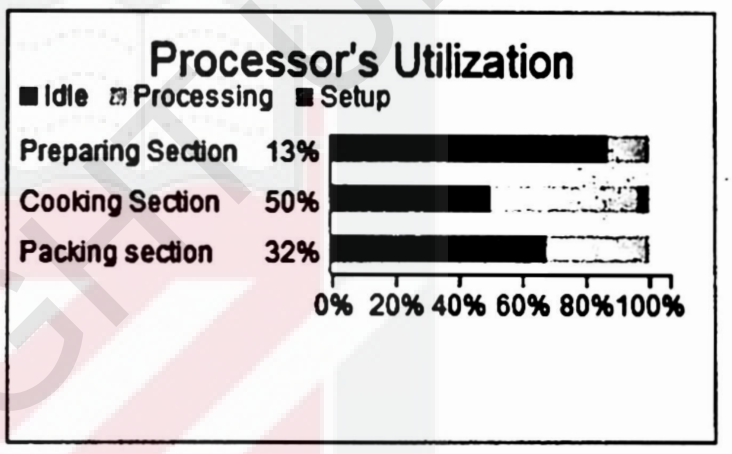
Figure 4.22(c)	Figure 4.22(d)
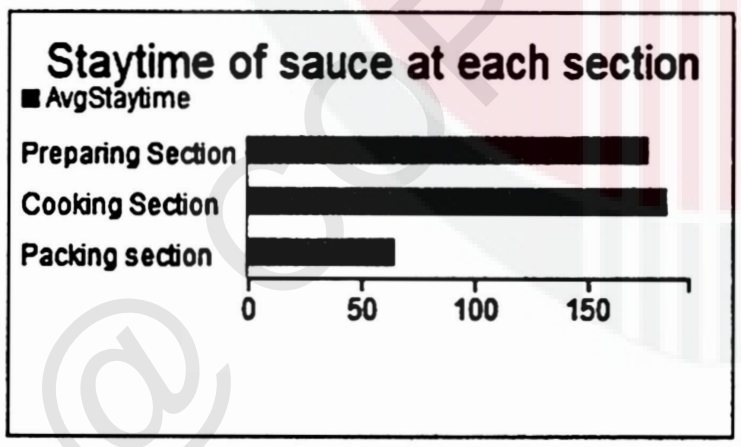	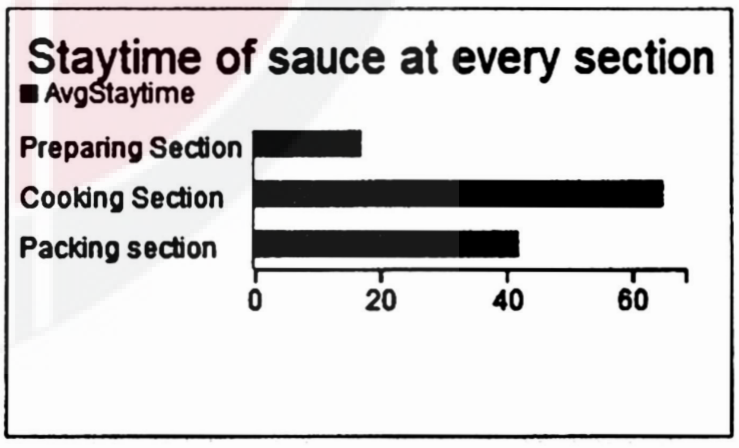
Figure 4.22€	Figure 4.22(f)

Figure 4.22. Simulation results of sauces products for current premise and New Factory X

Current premise	New Factory X
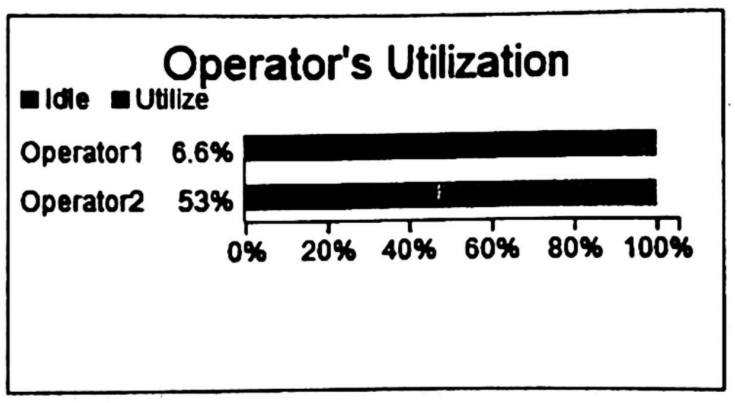	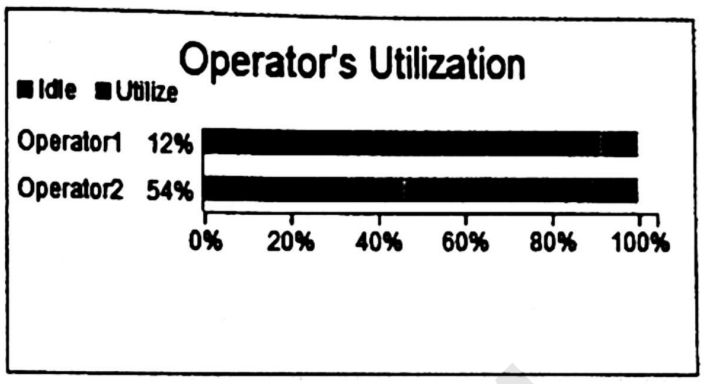
Figure 4.23(a)	Figure 4.23(b)
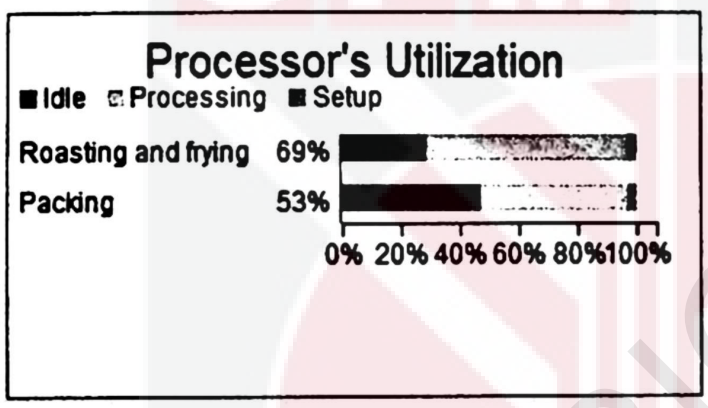	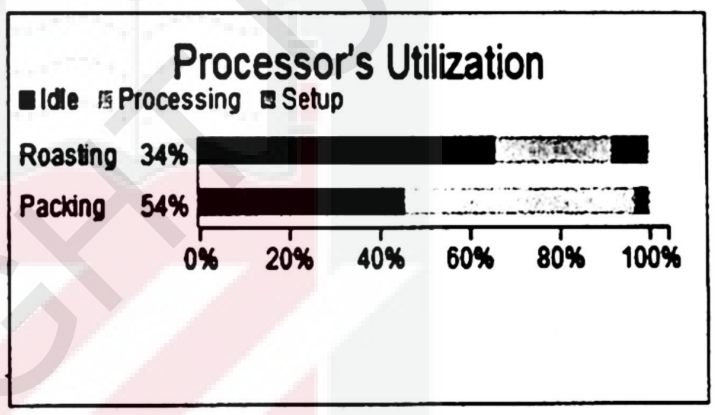
Figure 4.23(c)	Figure 4.23(d)
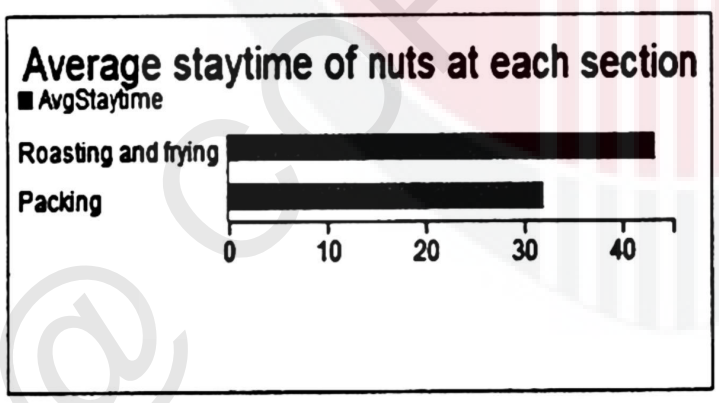	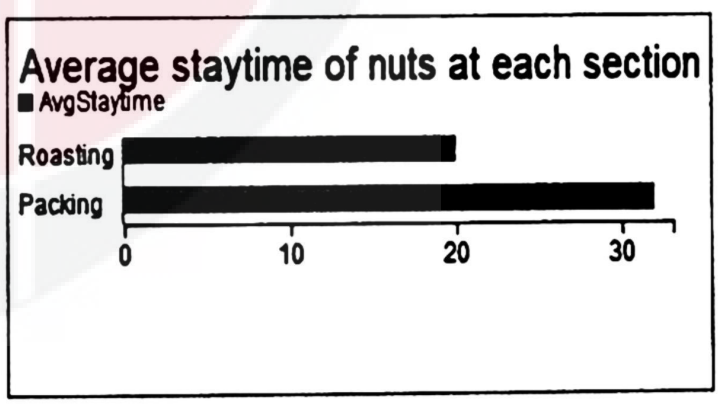
Figure 4.23(e)	Figure 4.23(f)

Figure 4.23. Simulation results of roasted nut products for current premise and New Factory X

4.3.2 Hygienic Design

The overall percentage score obtained for the 10 principles are summarized in Figure 4.24 below. The total score is 1000. The new factory X has an overall score of 96%.The design has scored full marks in most principles except for Principle #1(hygienic zoning), Principle #5 (site elements), Principle #6 (building envelope) and Principle #8(building component& structure). Yet, the scores are still higher than that of company X' premise. Principle#1 could not obtain full score because of the failure in providing auxiliary facility for different risk area. This is due to the This is due to the limited space availability. Failure to obtain full score in Principle #5, Principle #6 and Principle #7 is due to the fact that new Factory X design has not covered the decision on the premise selection. The decision is solely made by the company. As a result, the structure of the factory premise such as the existing roof flashings system and the space limitation are found to reduce the score. Nonetheless, the unsatisfactory requirements do not necessarily violate by the local GMP standards since some of these requirements are too rigid and there are other options to achieve the same hygiene objective. With 96% score, the new Factory X design is expected to be ready for GMP and HACCP system. Nonetheless, a continuous improvement at a very least expense is expected to be executed when required.

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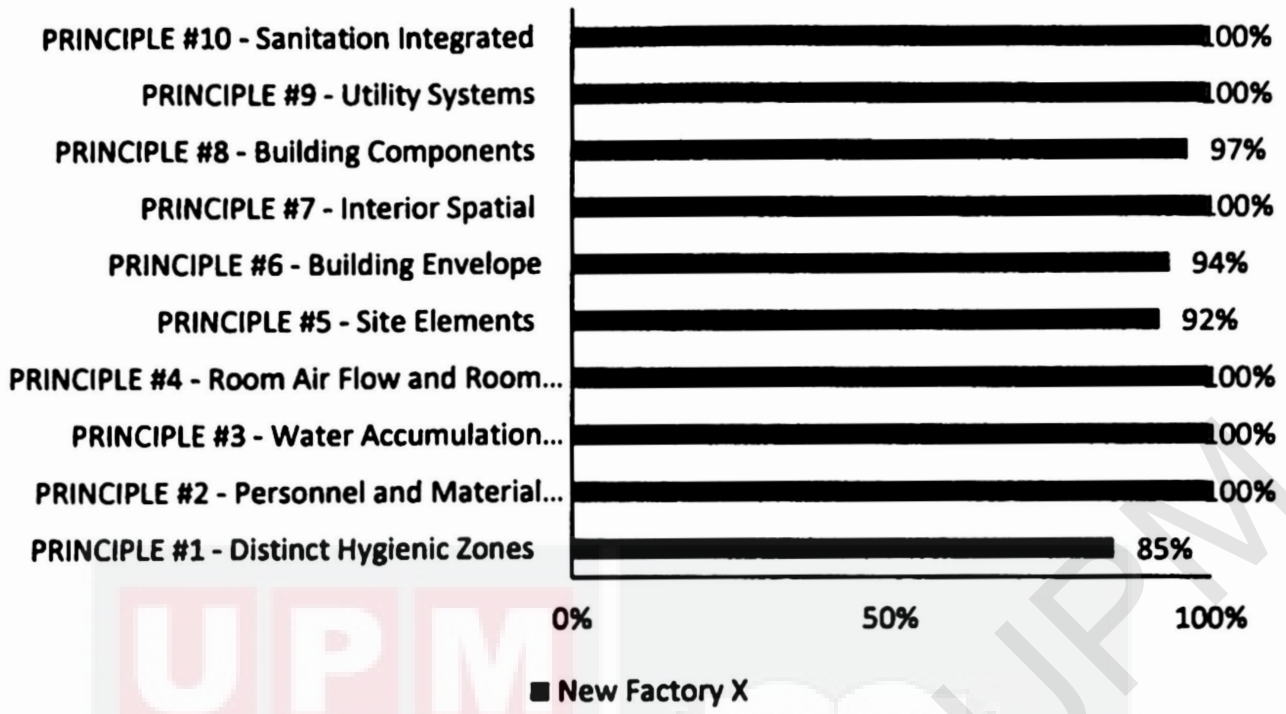

Figure 4.24. Score percentage of new Factory X design in the ten principles

4.3.3 Economic Analysis

Based on Table 4.17, the Return On Investment (ROI) of new Factory X for the first three years is 63% , 75 % and 87% respectively. The payback period of the new Factory X is just in 2 years. The Return On Investment (ROI) of the company is high due to the low cost spend on purchasing the raw materials for the products and the affordable price of products. The payback period for the company also short and this is due to the high profit margin of the products.

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Table 4.17. Summary economic data

Details	Year		
	2020	2021	2022
Utilities and structures			
Structures renovation	65000.00		
Lighting	1000.00		
Ventilation	7000.00		
Commercial water treatment system	5826.00		
Piping, communication and electrical	12000.00		
Fire safety	2000.00		
Security	500.00		
Waste treatment	5243.40		
Cold room (free installment)	35000.00		
Production line (yam bean)			
Customized production line (abrasive peeler, sorting conveyor, cutting,spray washing, drying)	72253.45		
MAP packing	15320		
Braising kettle	47280		
Roasting machine	7088		
Other (printing, sealer material handling, worktable)	12000		
Set-up cost (incl deposit)	28751.085		
Total start-up cost	316261.94		
Projected sales	860000	946000	1032000
Operating cost			
Raw material	344000.00	378400.00	412800.00
Paying rent	36000.00	36000.00	36000.00
Wages	180000.00	180000.00	180000.00
Overhead	30000.00	48000.00	58000.00
Maintenance	3000.00	3500.00	4000.00

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Table 4.17 continued.

Marketing	4000.00	1800.00	1800.00
Transport	9000.00	9000.00	9000.00
Administrative	10000.00	7000.00	8000.00
Bank	46285.00	46285.00	46285.00
Total operating cost	662285.00	709985.00	755885.00
Net income	197715.00	236015.00	276115.00
ROI	0.63	0.75	0.87
Cumulative net income	197715.00	433730.00	709845.00
Payback Period	Two years		

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CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Low productivity and hygiene problem has been faced by most SMEs in Malaysia and thus, resulting them to be not competent among the other multinational companies in food industry. These problems can be source back to the poor design of the food factory that overlook aspects related to production efficiency and hygienic design. Thus, a new factory X has been designed to provide an efficient factory system and a hygienic operation. The new factory was designed using 9 stages that integrates the Good Manufacturing Practice (GMP) design aspects and considers the productivity requirement by the market. The 9 design stages include the system requirement and constraint analysis, production planning, process development, machine selection and capacity planning, auxiliaries facilities design, space and manpower allocation, layout and building design and utilities requirement planning. The new factory has Production Program of 42560 kg/year, reserve capacity of 20%, Modified Atmosphere Packaging (MAP) processes, optimizes machines' capacity as well as has efficient spine layout, adequate number of facilities and utilities supplies. Simulation analysis with FlexSim software showed that the productivity of the

new factory was increased by 2 times for all products, while the production lead time was reduced by 17% for slice yam bean, 90% for sauces and 67% for roasted nuts. The improvement was due the designated continuous line, tangible Production Program for all four types of products (fresh-cut yam bean, red sauce, soy-based sauce and roasted nuts), optimized machines capacity and layout arrangement. The designated continuous lines eliminate the need for manual transfers between workstation and utilize less operators, whereby this saves production time. The correct machines' capacity in accordance to Production Program was able to meet the required production quantity and delivery time as demanded by customers. The layout arrangement in form of spine configuration was able to minimize distance between workstations and hence, reduce the movement and processing time of all processes in the simulation.

Meanwhile, the analysis with Hygienic Checklist Tool shows that the new design complied with majorities of hygiene requirement (96%) thus, ready for implementing GMP once the operation is run. This include separation of low and high risk area, material and personnel flow, airflow, spatial design and building structures specification. In conclusion, an efficient and hygienic food factory system can be achieved when the productivity and GMP requirement were implemented during the design process.

5.2 Recommendation

For future study, it was recommended that the design of factory would be extended to other planning aspects related to utilities supplies which includes ventilation system, lighting health and safety, piping, compressed air, electrical appliance, water supply waste water treatment. The planning can be conducted based on the determined plant capacity in this study. The utilities planning is considered important as interruption of utilities

supplies such as insufficient refrigeration, shortage of compressed air (for cutting processes) and inadequate lighting can slow the production operation and therefore affect the productivity as well as hygiene practice among the workers.

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REFERENCES

Alam, S. S., Jani, M. F. M., Senik, Z. C., Domil, A. K. A. (2010). Assessing barriers of growth of food processing SMIs in Malaysia: a factor analysis. *International Business Research, 4*(1), 252.

Altiok, T., Melamed, B. (2007). Simulation modeling and analysis with Arena. New York: Academic press.

Amit, N., Suhadak, N., Johari, N., Kassim, I. (2012). Using simulation to solve facility layout for food industry at XYZ Company, presented at Humanities, Science and Engineering Research IEEE Symposium, 2012.

Arya, S.S.(1992). Convenience foods emerging scenario. Indian Food Ind. 11(4):31-41.

Career Centre. (2017). Program Latihan Kemahiran Makanan Industri Kecil Dan Sederhana B40 (PLKB40). Retrieved from https://careercentre.com.my/kursus-kemahiran-makanan-iks-program-latihan-kemahiran-b40-plkb40/brochure-design1/

Darmawan, R. (2002). *Improvement studies on manufacturing operation design for MINT pilot plant (Unpublished master dissertation).* Universiti Putra Malaysia, Malaysia.

Department of Statistics Malaysia (DOSM). (2011). Profile of Small and Medium Enterprise.. Putrajaya, Malaysia.

Donk, D. P. V. A. N., & Gaalman, G. (2004). Systematic Layout Planning of Food Processes, 82(November), 1485–1493.

Dwijayanti, K., Dawal, S. Z. M., Jamasri, N. V., & Aoyama, H. (2010). A proposed study on facility planning and design in manufacturing process. In Proceedings of theInternational MultiConference of Engineers and Computer Scientists 2010, IMECS 2010.

Economic Census 2016. (2017). Mystate Statisctic. Retrieved from https://www.dosm.gov.my/v1/index.php?r=column/pdfPrev&id=WEVEUi8zaytMbFpncC9vTDN4TmZQQT09

European Hygienic and Engineering Design Group (EHEDG). (2004). DOC 8 Hygiene Equipment Design Criteria. Frankfurt, Germany.

Food Safety and Quality Division (FSQD). (2015). *List of GMP-certified companies*.Putrajaya, Malaysia.

Grocery Manufacturers Association (GMA). (2016). Board, Councils & Committees. Retrieved from http://www.gmaonline.org/about/board-councils-committees/

Hasnan, N. Z. N., Aziz, N. A., Zulkifli, N., & Taip, F. S. (2014). *Food Factory Design: Reality and Challenges Faced by Malaysian SMEs. Agriculture and Agricultural Science Procedia, 2, 328–336.* doi:10.1016/j.aaspro.2014.11.046

Hasnan, N.Z.N., Ab Aziz, N., Taip, F.S. and Zulkifli, N. (2018). Spine layout design for improving food hygiene and reducing travelled distances in a small-scale burger patties processing. Food Research. Advanced Online Publication. https://doi.org/10.26656/fr.2017.3(4).149

Hat, Z. (2014). Nikmat Sengkuang calit. *Berita Harian* .

Hecker, F., Hussein, W., Becker, T. (2010). Analysis and optimization of a bakery production line using ARENA. International Journal of Simulation Modelling, 9(4), 208-216.

Holah, J., Lelieveld, H. L. (2011). Hygienic design of food factories. Cambridge: Woodhead Publishing.

Ismail, M.M., & Yusop, Z. (2014) Competitiveness of the Malaysian Food Processing Industry. Journal of Food Products Marketing, 20:sup1, 164-178

Jali, M. B., Ghani, M. A., Nor, N. M. (2016). The Confusion of Design and Facilities in Good Manufacturing Practice Requirements among Industries in Malaysia. *Environment- Behaviour Proceedings Journal, 1*(3), 156-167.

Jung, R. (2010). *Fabrikplanung*. Department of Facility Design and Management, Albstadt- Sigmaringen University. Sigmaringen, Germany.

Manzini, R., & Accorsi, R. (2013). The new conceptual framework for food supply chain assessment. *Journal of Food Engineering, 115*(2), 251–263 from https://doi.org/10.1016/j.jfoodeng.2012.10.026

Malaysian Association of Standard Users. (2015). Building consumers' trust and confidence in food safety system in Malaysia. Standard Users.1 (2), 3.

Malaysian Investment Development Authority (MIDA). (2018). *Malaysia's Food Industry.*Kuala Lumpur, Malaysia.

Musa, H., & Chinniah, M. (2016). *Malaysian SMEs Development: Future and Challenges on Going Green. Procedia - Social and Behavioral Sciences, 224, 254–262.* doi:10.1016/j.sbspro.2016.05.457

Nielsen Global Survey of Snacking. (2014). Nielsen Global Snacking Report. Retrieved from https://www.nielsen.com/content/dam/nielsenglobal/kr/docs/global-report/2014/Nielsen%20Global%20Snacking%20Report%20September%202014.pdf

Nikoleiski, D. (2012). Principles of hygienic design. Journal of Hygienic Engineering and Design, 1, 15-18.

Nor, N. G. M., Bhuiyan, A. B., Said, J., Alam, S. S. (2017). Innovation barriers and risks for food processing SMEs in Malaysia: A logistic regression analysis. *Geografia: Malaysian Journal of Society and Space, 12*(2), 167-178.

Ojaghi, Y., Khademi, A., Yusof, N. M., Renani, N. G., & bin Syed Hassan, S. A. H. (2015). Production layout optimization for small and medium scale food industry. Procedia Cirp, 26, 247-251.

Rani, R. M., Ismail, W. R., Ishak, I. (2014a). An integrated simulation and data envelopment analysis in improving SME food production system. World Journal of Modelling and Simulation, 10(2), 136-147.

Rani, R. M., Ismail, W. R., Razali, S. F. (2014b). Operator performance evaluation using multi criteria decision making methods. *AIP Conference Proceedings, 1602*(1), 559-566.

Rosli, L. (2018, December 19). Matrade urges SMEs to capitalise on Msia's position as trade nation. *The Straits Times*.

Sa'udah, N., Amit, N., & Ali, M. N. (2015). Facility layout for SME food industry via value stream mapping and simulation. Procedia Economics and Finance, 31, 797-802.

Saravacos, G. D., Kostaropoulos, A. E. (2002). Handbook of food processing equipment. New York: Springer.

Saxena, A. J. (2017). Convenience foods : Foods of the future, 1(6), 5–10.

Shawal , Z. (2014).Sengkuang Calit Popular di KPTM. *Berita Harian* .

SME Corporation Malaysia (SMECORP). (2016). *SME Annual Report 2015/16 Embracing Changes (2016)*. Kuala Lumpur, Malaysia.

SME Corporation Malaysia (SMECORP). (2018). RMKe-11. Retrieved from http://smeinfo.com.my/my/polisi-peraturan/polisi-rmk-11

SME Corporation Malaysia (SMECORP). (2019). *SME Mentoring Programme.* Kuala Lumpur, Malaysia.

Standards and Industrial Research Institute of Malaysia (SIRIM). (2009). Malaysian Standard 1514 Amalan Pengilangan Baik (MS1514:2009). Shah Alam, Malaysia.

Talib, H.H.A., Ali, K.A.M., Idris, F. (2013). Quality Management Framework for the SME's Food Processing Industry in Malaysia. International Food Research Journal 20(1), 147-164.

The Business Times, 2014. Top Five Risks SMEs Should Address. The Business Times.

Uniform Building By-Laws (UBBL). G.N. 5178/85. (1984).

Zain, Z. M., Anas, Y., Hassan, F. H., Lehar, H., Shamsuddin, S. (2012). Challenges, opportunities and performance of Bumiputera SMEs in the food industry: A Malaysian perspective, presented at Innovation Management and Technology Research (ICIMTR), Malacca City, 2012.

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APPENDICES

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GMA Facility Design Checklist

Version 1.0 - June 2010

	For detailed directions on the use of the checklist, please click on the tab marked "Directions."							
	Date:							
	Completed By:							
	Location:							
	Facility purpose:							
	Facilities, equipment and machinery must meet all federal, state and local food safety requirements as well as personnel safety requirements during operation, cleaning and sanitizing. Any modifications must not affect compliance with these requirements.							
#	Description	S	M	U	NA	Comments	Points Awarded	Points Available
	PRINCIPLE #1 - Distinct Hygienic Zones Established In The Facility							
1.01	Facility drawings show hygienic zones, (Ready-to-eat vs. raw, high care vs. low care, etc.) where applicable. Hygienic zones should be clearly demarcated on the plant schematics with colors or other markings to facilitate easy identification						25.0	25.0
1.02	Separate locker rooms and lunch rooms should exist for RTE/high risk and non-RTE/lower risk personnel, or provisions to separate high risk and low risk employees exist						25.0	25.0
1.03	Restroom facilities are not located in RTE/high risk zones (see point 10.08)						25.0	25.0

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1.04	Separate storage areas for tools and spare parts exist to minimize contamination from non-RTE/lower risk zones to RTE/high risk zones		X				12.5	25.0
1.05	Separate quality labs should exist for RTE/high risk and non-RTE/lower risk zones		X				10.0	20.0
1.06	Separate storage areas for sanitation crews exist for RTE/high risk and non-RTE/lower risk zones (e.g., vacuums, mops, brooms etc. are segregated)						30.0	30.0
TOTAL POINTS FOR THIS SECTION							127.5	150.0
PRINCIPLE #2 - Personnel and Material Flows are Controlled to Reduce Hazards								
2.01	Facility is designed such that movement of employees and visitors throughout the facility is controlled in a manner that does not contribute to potential cross contamination (e.g., employees working with raw product travel separate paths from those working with RTE product)					Employees and visitors need to go through changing and hand wash before entering processing area. Separate path for workers with high risk and low risk was provided.	25.0	25.0
2.02	Facility is designed such that movement of contractors and maintenance personnel throughout the facility is controlled in a manner that does not contribute to potential cross contamination (such as separate areas)					They are required to enter the change room and hand wash station before entering processing area.	20.0	20.0
2.03	Facility is designed to provide sanitary delivery of packaging materials, ingredients, and rework into RTE/high risk zones in a manner that does not contribute to potential cross contamination					Material other than food transfered to high risk room through hatch	25.0	25.0
2.04	Facility is designed for sanitary removal of trash from RTE/high risk zones (e.g., dedicated personnel/ travel paths/ dedicated and sanitized footwear for high to low hygiene areas)					Removal of trash from high risk through hatch entering the low processing area and then outside of facility. (Waste flow)	30.0	30.0
TOTAL POINTS FOR THIS SECTION							100.0	100.0
PRINCIPLE #3 - Water Accumulation Controlled Inside Facility								
3.01	Floor design and drainage systems prevent standing water and avoid drain backups						20.0	20.0

3.02	Wall and curb surfaces drain freely without pockets, ledges and nooks						15.0	15.0
3.03	Areas above ceilings do not accumulate water						15.0	15.0
3.04	Equipment wastewater discharges are piped directly to drains						20.0	20.0
3.05	Drain pans are sloped to be free draining						15.0	15.0
3.06	All drip pans have continuous flow and are directed to a drain						15.0	15.0
TOTAL POINTS FOR THIS SECTION							100.0	100.0
PRINCIPLE #4 - Room Air Flow and Room Air Quality Controls								
4.01	Room temperature meets process requirements						15.0	15.0
4.02	Measures are taken to prevent condensation through all seasons						20.0	20.0
4.03	Facility airflow is from clean to less clean areas (high hygiene to low hygiene, high to low risk zones, RTE to non-RTE areas)						15.0	15.0
4.04	Critical process air is adequately filtered						10.0	10.0
4.05	Outdoor makeup air is properly filtered for the process requirements						15.0	15.0
4.06	Air handling system components meet the 10 Principles of Equipment Sanitary Design						15.0	15.0
4.07	Where appropriate, provisions are made to capture high concentrations of heat, moisture and particulates at the source						10.0	10.0
4.08	HVAC/refrigeration system components are located to avoid risks of product contamination						15.0	15.0
4.09	HVAC/refrigeration systems are dedicated to specific areas (RTE vs. non-RTE) and do not contribute to cross-contamination						10.0	10.0
TOTAL POINTS FOR THIS SECTION							125.0	125.0

PRINCIPLE #5 - Site Elements Facilitate Sanitary Conditions								
5.01	Driveways, parking lots and pedestrian walkways are paved and self draining					Cement	5.0	5.0
5.02	Landscaping and grounds are designed to minimize attraction and harborage of insects and rodents					No bushes and grass , covered drain, pavement	5.0	5.0
5.03	Adequate trash receptacles in pedestrian traffic areas are provided. Receptacles shall be covered and/or managed to not be a source of contamination					Covered waste bin	5.0	5.0
5.04	Insect attractant lighting is positioned to draw insects away from the building. Lighting on the building limits the attraction of insects		X				5.0	10.0
5.05	Roof surfaces should be cleanable and self draining					Material, Sloping	5.0	5.0
5.06	Finished floor elevation is higher than adjacent grades to prevent storm water ingress into building					Floor elevation up to 50 mm	5.0	5.0
5.07	External operations (e.g., trailer cleaning, bulk storage, trash and waste management) are designed and positioned to prevent unsanitary impact (splashing, overflow, cross contamination, residues etc.) on the facility					Waste bins covered, avoid prevailing wind, drainage not go through factory (outside)	5.0	5.0
5.08	External drainage is adequate to prevent standing water						5.0	5.0
5.09	Detention and retention basins are properly designed, maintained and operating to eliminate unnecessary standing water						5.0	5.0
5.10	A minimum 30" wide border of asphalt, gravel or concrete border or other acceptable material, is present on all exterior sides of the facility						5.0	5.0
5.11	Space is provided for storage of clean portable equipment				X	No portable equipment	0.0	0.0
5.12	Soiled laundry collection locations are established, where applicable				X	Outsourced to laundry outside	0.0	0.0
5.13	Space is provided for boot storage and cleaning, where applicable				X	Only has boot storage.Cleaning of boot is done in Cleaning Room, at different time of production cleaning, followed by sterilizatioan.	0.0	0.0

5.14	Trash collection is located in a manner that does not pose a risk to the product or the facility, and in locations that are cleanable and maintainable					Trash collection is at the back of building, enclosed by wall.	10.0	10.0
TOTAL POINTS FOR THIS SECTION							60.0	65.0
PRINCIPLE #6 - Building Envelope Facilitates Sanitary Conditions								
6.01	Building envelope (e.g., shell, skin) is constructed of materials that are solid, impervious, and free of cracks and voids, and are compatible with cleaning methods					Building material lined from food-grade material	10.0	10.0
6.02	Roof flashing systems prevent harborage of insects, birds and rodents					Existing roof structure does attract birds harbourage	0.0	5.0
6.03	Roof is sloped to provide positive drainage						5.0	5.0
6.04	Roof drainage is not a source of contamination						5.0	5.0
6.05	Canopies are totally closed						5.0	5.0
6.06	All louvers, fans, vents and openings have intact insect screens and are insect proof and/or self-closing					AHU of food-grade with screens	5.0	5.0
6.07	Doors are impervious, fully weather stripped, fit well and have solid cores					Door design of food-grade	5.0	5.0
6.08	All door jams and window sills are firmly anchored to the slabs and fully filled					Door design of food-grade	5.0	5.0
6.09	Window frames and door headers are fully filled and mounted flush with walls to eliminate edges					Door design of food-grade	15.0	15.0
6.10	All voids associated with utility penetrations (e.g., electrical weather heads, gas mains, sprinkler risers) are fully filled with appropriate materials, then sealed						5.0	5.0
6.11	All concrete wall panels are caulked from roof to footing					Yes	10.0	10.0
6.12	Dock doors have a dock seal or shelter and are weather stripped					Vertical dock door with seals	5.0	5.0

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6.13	Dock pits, dock plates and levelers are designed to be cleaned and proper utilities are in place to facilitate proper cleaning					Water tap is available with at receiving or shipping facility	5.0	5.0
TOTAL POINTS FOR THIS SECTION							80.0	85.0
PRINCIPLE #7 - Interior Spatial Design Promotes Sanitation								
7.01	Aisles are wide enough for maintenance, sanitation and materials movement					Aisle size considers operator movement, material handling size and cleaning acticity	10.0	10.0
7.02	There is sufficient access to building elements (e.g., columns, beams, bracing) for cleaning					Yes	10.0	10.0
7.03	There is sufficient access to the wall-floor interface for cleaning					Through clearance	10.0	10.0
7.04	Stationary equipment is sufficiently placed to allow cleaning and sanitation underneath and above the equipment (18 inches for non-contact equipment and 30 inches for food contact surfaces)					20 cm above floor and >45 cm from the wall	5.0	5.0
7.05	The layout is coordinated to allow access to clean and inspect overhead elements (e.g., ducts, piping, equipment, lights, diffusers)					The cabling used conduit (smooth stainless steel) that run vertically to the equipment without (suspended over food material)	5.0	5.0
7.06	There is a perimeter inspection zone of at least 18 " between walls and any storage or placement of fixed equipment					45 cm to 1 m	20.0	20.0
TOTAL POINTS FOR THIS SECTION							60.0	60.0
PRINCIPLE #8 - Building Components and Construction Facilitate Sanitary Conditions								
8.01	Interstitial spaces separate process areas from utility services and overhead structural components, and are accessible for cleaning					Roof void can be accessed	5.0	5.0
8.02	Suspended ceilings should be avoided whenever possible. If absolutely necessary, a walk-on design should be used to allow personnel access for cleaning and they shall be smooth, cleanable and at a uniform height					Height, access through back-area	5.0	5.0

8.03	Walls, and ceilings are smooth and cleanable with minimal joints and no cavities				Food-grade material	5.0	5.0
8.04	All vertical and horizontal wall joints are sealed appropriately				Food-grade joint	5.0	5.0
8.05	All vertical surface to floor junctions have a cove and surfaces that are free of pits, erosion and voids				Coving design	5.0	5.0
8.06	Concrete surfaces are solid, smooth, and free of pits, erosions and voids					5.0	5.0
8.07	Curbs (stainless steel, concrete and concrete with stainless steel inlay) go the full height to the curb-wall junction				No curb design	5.0	5.0
8.08	Wall facings such as Fiberglass Reinforced Panels (FRPs) and Insulated Metal Panels (IMPs) are factory laminated or foamed-in-place for insulation (Check federal, state and local building code requirements)					5.0	5.0
8.09	Cavity and voids are absent in floor, wall and ceiling assemblies. All floor joints and cracks are sealed					10.0	10.0
8.10	Insulation that does not deteriorate, or retain or absorb moisture, such as closed cell or encapsulated insulation, is used in the facility					5.0	5.0
8.11	Horizontal structural members have no flat surfaces where dust or soil could accumulate					5.0	5.0
8.12	All-thread rods and "Unistruts" are not used and other threaded surfaces are minimized					5.0	5.0
8.13	Bases of drains are supported to prevent settling					5.0	5.0
8.14	All cracks, joints and voids are filled with appropriate materials					5.0	5.0
8.15	Caulking is minimized and done in a manner that is not a source for potential contamination (e.g., loose, flaking)					5.0	5.0
8.16	Items attached directly to a building surface have stand-offs		X			2.5	5.0

8.17	All mezzanine structures over a processing area are waterproof and drain properly				X		0.0	0.0
8.18	Doors and windows are constructed to prevent insect and rodent access, and harborage, are impervious, easily cleanable and resistant to wear and corrosion						5.0	5.0
8.19	Floors are constructed to prevent insect and rodent access and harborage, are impervious, easily cleanable and resistant to wear and corrosion						5.0	5.0
TOTAL POINTS FOR THIS SECTION							92.5	95.0
PRINCIPLE #9 - Utility Systems Designed To Prevent Contamination								
9.01	Horizontal piping, conduits, and light fixtures are not installed above exposed product or processing equipment						5.0	5.0
9.02	Piping and conduits are located and spaced to facilitate access, cleaning and sanitation, and are routed outside of process areas wherever possible						5.0	5.0
9.03	Piping is adequately insulated to prevent condensation and the insulation is covered with material able to withstand the operating conditions and the cleaning methods used						5.0	5.0
9.04	Lockable fasteners are used on hangers and attachments to avoid risk of foreign material contamination						5.0	5.0
9.05	Glass components are used only where necessary, and are properly protected (e.g., shields or shatterproof coated) to avoid risk of foreign material contamination						5.0	5.0
9.06	Controls are in place to prevent moisture accumulation in air lines and minimize potential transfer of moisture through compressed air				X		0.0	0.0
9.07	Air gaps or mechanical backflow prevention devices, are used to prevent cross-contamination of the potable water supply						5.0	5.0

9.08	Where steam will contact product, or product contact surfaces, the steam supply system shall conform with requirements for the production of culinary steam				X		0.0	0.0
9.09	Bulk ingredient tanks are designed for proper cleaning and are accessible for regular inspection				X		0.0	0.0
9.10	Process and sanitary sewers are separated within the building						5.0	5.0
9.11	Waste and vent lines are not routed above product or process equipment						5.0	5.0
9.12	Where possible, drain cleanouts are installed outside the processing areas						5.0	5.0
9.13	Drains are accessible for cleaning and sanitation						5.0	5.0
9.14	Trench drains are avoided wherever an alternative is possible						15.0	15.0
9.15	Process sewers are made of materials compatible with the temperature and corrosiveness of the waste stream and cleaning compounds used						5.0	5.0
9.16	Air (gas) discharges from sewage lines, drain lines, and raw process areas are not vented in a manner that may contaminate air intakes						5.0	5.0
9.17	Sewage, drain lines, and air discharges from raw process areas are vented at least twelve inches below the level of fresh air intakes when located within 50 feet of each other (as these gases are typically heavier than air)						10.0	10.0
9.18	Drains are designed to avoid ingress of drain gasses into process areas (e.g., 'P' traps or other methods)						5.0	5.0
9.19	Interior drain lines do not run through high risk/high hygiene processing areas						5.0	5.0
TOTAL POINTS FOR THIS SECTION							95.0	95.0
PRINCIPLE #10 - Sanitation Integrated Into Facility Design								

10.01	Water temperature, flow and pressure meets specified requirements at point of use					10.0	10.0
10.02	Clean up stations are supplied with adequate hose hangars to keep hoses off the floor and where possible outside of process areas					10.0	10.0
10.03	Rinse systems must be designed to deliver the minimum pressures needed to complete the desired cleaning procedures					10.0	10.0
10.04	Adequate hand washing and sanitizing stations are provided at locations as required to maintain adequate hygiene requirements					10.0	10.0
10.05	Adequate interventions (e.g., hygiene junctures, foot baths, doorway foamers, boot washers) are provided at locations as required to maintain zones of control					10.0	10.0
10.06	Adequate systems (e.g., vacuum systems, dust collection systems, COP, CIP, equipment washers) are provided to facilitate proper cleaning, sanitizing and drying of equipment					10.0	10.0
10.07	Microbiology laboratories are located and constructed in a manner to prevent potential contamination to process areas (e.g., located in separate buildings, double door entries, negative air pressure)					10.0	10.0
10.08	Restrooms do not open directly from or into any processing area					10.0	10.0
10.09	Restrooms are designed to maintain negative air pressure versus their surrounding area					5.0	5.0
TOTAL POINTS FOR THIS SECTION						85.0	85.0