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Model Development of Cold Chains for Fresh Fruits and Vegetables Distribution: A Case Study in Bali Province

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Abstract. In developing countries such as Indonesia, as much as 40% of total vegetables and fruits production becomes waste because of lack refrigeration. This condition also contributes a food crisis problem besides other factor such as, climate change and number of population. Cold chain system that will be modelled in this study is for vegetables and fruits and refrigeration system as the main devices. In future, this system will play an important role for the food crisis solution where fresh food can be distributed very well with significant low waste. The fresh food also can be kept with good quality and hygienist (bacteria contaminated). Cold Chain model will be designed using refrigeration components including, pre cooling chiller, cold room, and truck refrigeration. This study will be conducted by survey and observation di around Bali Province focus on vegetables and fruits production center. Interviews and questionnaire will be also done to get some information about the conventional distribution obstacles and problem. Distribution mapping will be developed and created. The data base of the storage characteristic of the fruits and vegetable also collected through experiment and secondary data. Depend on the mapping and data base can be developed a cold chain model that has the best performance application. The model will be can directly apply in Bali to get eligible cold chain in Bali. The cold chain model will be compared with the conventional distribution system using ALCC /LCC method and also others factor and will be weighted to get better results.

1. Introduction

In recent years, the food security problem becomes an important issue which should be solved with some alternative solutions. In Indonesia, this problem is mainly due to the high population growth which reaches 10% per year with an estimated 400 million people in 2050 [1]. In addition, high urbanization cause decreasing agriculture productivity in rural area and it will become a major problem if not provide adequate infrastructure [2]. It is also affected by El Nino (climate change) that causes prolonged drought. Especially for the Province of Bali this food problem is also getting worse because of the high conversion of agricultural area to inhibited area . Data from BPS of Bali Province [1] examine that at least 100 hectares of lost productive agricultural land per year.

Besides that main factors mentioned above, food insecurity is also caused by poor distribution and storage systems, especially for fresh fruits and vegetables. With conventional systems, abundant production at harvest time will not be stored and distributed well to the consumer. In developing countries losses are dumped into garbage fresh vegetables and fruits account for 40% of their total



production while for comparison in developed countries only produces waste of 15%, this is caused by not getting adequate cooling system [3],[9].

In more detail, the high waste is due to lack of cold storage, poor logistics systems, ineffective cold chain facilities and poor supporting infrastructure [4]. As a tropical area, the rate of decomposition (spoilage rate) of fresh fruit and vegetable products is very high without cooling as a result of high temperature and humidity environment. While modern and standardized distribution systems have been applied generally in developed countries, the distribution process from suppliers to consumers is carried out with controlled temperatures according to the conditions of the distributed products. In the case of primarily honey products and vegetables, the temperature should be controlled from 0 ° C to 5 ° C [5].

Bali Province, population growth in urban areas is very rapid and has not been matched by the supply of adequate vegetable and fruit products. The demand for this commodity is very high. And the quality and hygienic of these products are still relatively low because of the liquefied use of cooling infrastructure for post-harvest distribution, particularly products from local farmers. So, this study is aim to simulate an appropriate and applicable cold chain system for fresh vegetables and fruits application in Bali Province

2. State of the arts

For vegetable and fruit products post-harvest storage is very important because it is associated with the deterioration rate caused by changes due to biochemical processes and due to microorganisms [5]. Temperature is very important in this case. In the storage of horticulture products (medium temperature), of course the specifications / characteristics of each product requires different conditions. In general, the storage of fresh vegetables and fruits ranges from 0 ° C to 15 ° C with relative humidity (RH) ranging from 90 to 95% and post-harvest can last between 3-6 weeks. Even for the food industry that used to store at temperatures above 0° C, has now lowered its temperature to between -18°C to -35°C in order to reduce or slow down physical, chemical and microbiological damage [6],[8]. While some local horticultural products such as durian, mangosteen, *duku* or chili need an average temperature of 10°C-15°C at 90% -95% realistic humidity for storage period of 2 weeks to 1 month and of course can be increased by storing storage temperature more low [7].

Refrigeration is used at all stages of the cold chain ranging from food processing (precooling, packing), distribution, retail and end-consumer households [6]. In addition Laguerrea et al.[3] reviewing the cooling components such as: Cold Room, refrigerated truck, display cabinets, Domestic refrigerators. Review is referred from various previous researches that the tools are meticulously using Computational Program Fluid Dynamics (CFD). Repair and development of equipment by modeling air velocity, moisture and designed to ensure air flow can be spread evenly throughout the room. ASHRAE [5],[10],[11] describes the pre-cooling method for vegetables and fruits. When the harvest occurs the process of heat dissipation is very fast before the vegetables are sent / distributed, stored or processed further. Immediate and precise pre-cooling can inhibit the development of rotting microorganisms, decrease enzymatic and respiratory activity, and decrease the loss of water content. Precooling can be done with various methods including: hydro cooling, vacuum cooling, air cooling, and contact icing. Cooling times start from a few minutes to 24 hours.

(James & James)[12] conducted a study of cold chain system that is commonly applied in European countries in terms of CO₂ emissions, it is found that the cold chain system which is a refrigeration system becomes a global passenger of carbon dioxide (CO₂) emissions of 1 %. As a result of global warming, the environmental temperature increases so it is also very influential on the development of cold chain system. In addition, with increasing environmental temperatures, can increase the risk of contaminated food and accelerate decay [13],[14], this will occur if not accompanied by improvement / improve the cold chain system. Thus, it is necessary to optimize the use of energy in cold chain system in order to decrease greenhouse gas emission [15],[16],[17].

3. Methodology

This study develop cold chain system model which will implement for fresh fruit and vegetable products and Bali Province condition as a case study, where data acquisition and analysis method are described as follows.

3.1. Data acquisition method

The research begins with surveys and data collection for the analysis and mapping of fruit and vegetable producing centers in the Province of Bali. The collection and data collection for the existing distribution system for fruit and vegetable producing center covering, Tabanan, Buleleng, Bangli, Karansem and Badung regencies. Data are collected by direct survey method and interview method to farmers, perpetrators small business in the field of horticulture especially for local distribution (province and inter province) and businessman for export. Analysis was also conducted on the types of vegetable and fruit products annually, environmental condition (temperature and humidity) analysis and distribution route from producer to consumer. Further analyzed storage characteristics of each product by cooling method. Furthermore, develop database system characteristics storage of all vegetable and fruit products that produced in the center farming area. This data base system will be manage with computer program application.

Furthermore, cold chain system model was developed depend on data and analyzed data obtained. The cold chains model was designed to comply the results of distribution route and economic conditions, the system covers the capacity of the required refrigeration equipment, the analysis of energy requirements, as well as the optimum storage conditions. The system is generally composed of component components including units, pre-cooling, transport refrigeration, cold room, cabinet display and domestic refrigerator. Furthermore, to ensure the system can run integrated, effective and efficient. It is necessary an optimum system design so as to obtain product quality that is maintained properly with the necessary energy as efficiently as possible. Cost analysis between conventional and cold chain systems was analyzed by LCC method.

3.2. Analysis method

In existing condition, distribution from farming area to market or consumers, in general not used adequate infrastructure of cooling system yet. The cold chain system is offered and modeled in this study Showed in Figure 1.

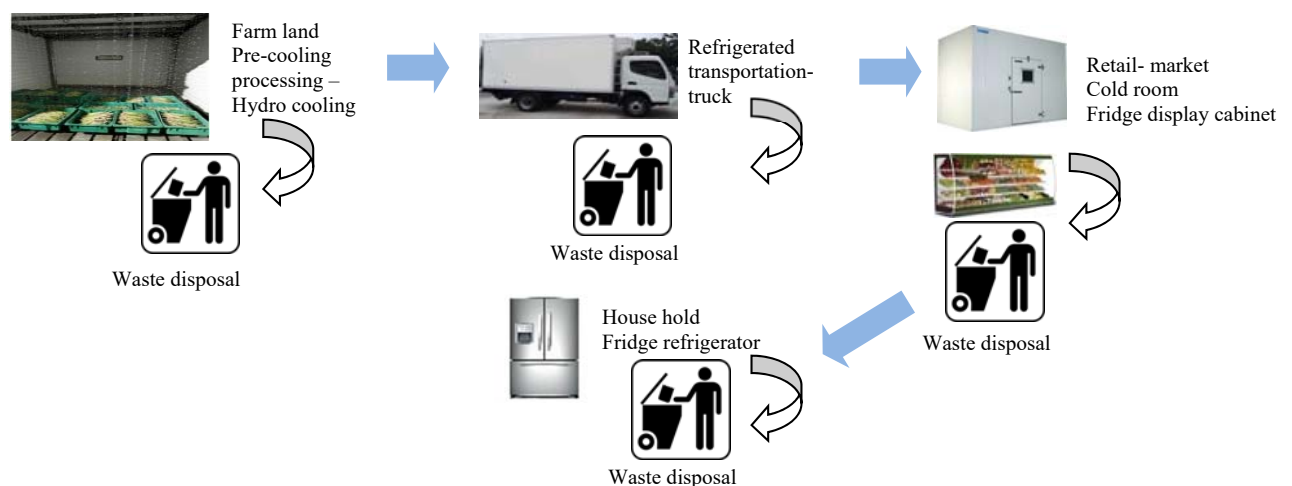


Figure 1. Infrastructure of cold chain to be modelled

Modeling or simulation will provide optimization on cold chain system with parameter analysis: i) types of products, ii) type of technology in cooling system, iii) energy requirements per product

weight, iv) operational time and v) costing (investment cost, operational and maintenance). The analysis is performed by cooling energy and cost analysis calculation using computer program.

4. Results and Discussions

Four main components were obtained in this study covering, mapping area of centre of specific vegetable and fruit areas in Bali Province in order to get the distribution route, developed model and calculating costing in order to show eligibility of the cold chains compare with the conventional system one.

4.1. Distribution and area centre of the Vegetables and fruits and cold chain model

Conventional distribution from farming area to the market (existing condition), in general go to Denpasar. Moreover, Kintamani’s oranges as an example get more widely market to the West Java and getting a drastic low price due to abundant harvest. Following Figures show general distribution route from farming are to the Denpasar City and surrounding (a), and the cold chain model introduce in this study (b).

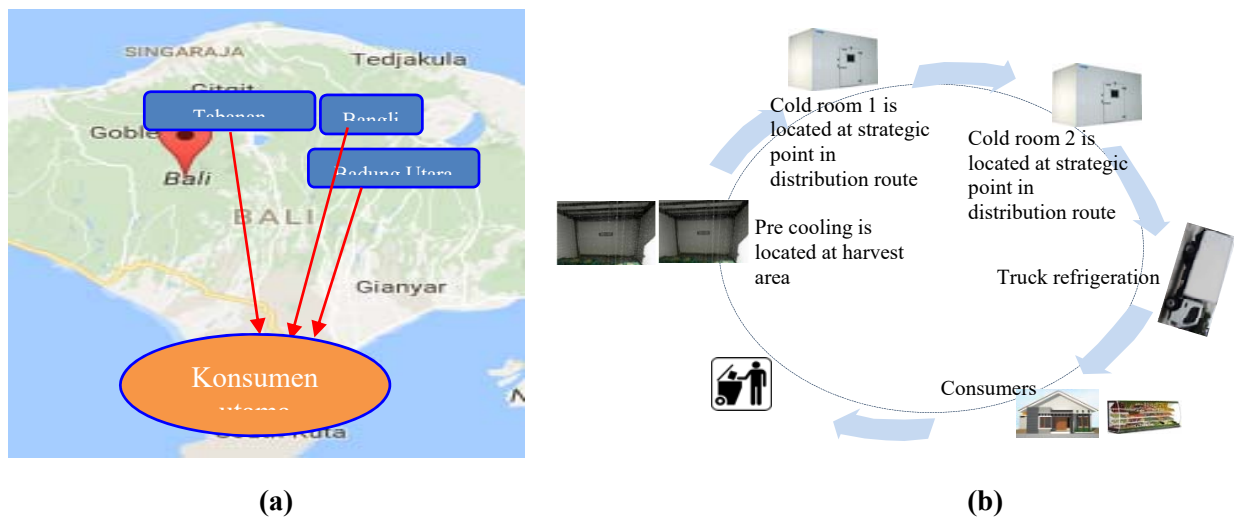


Figure 2. Distribution route and cold chains model

4.2. Characteristic fruits and vegetables storages

The temperature minimum of storage is 5°C and the highest temperature is around 16 °C with relative humidity (RH) vary from 65%, until nearly 100% as shown in Table 1. This data are used to calculate the refrigeration capacity model.

Table 1. Storage characteristic of main products

No	Products	Temperature (°C)	Humidity (%)	Storage time	No	Products	Temperature (°C)	Humidity (%)	Storage time
1	Asparagus	5	90-100	2-3 weeks	11	Orange	12	85-90	1-6 months
2	Small chili	5-10	85-95	2-3 weeks	12	Strawberry	5	90-95	4 days
3	Big chili	5-10	85-95	2-3 weeks	13	Mango	13	85-90	2-3 weeks
4	cabbage	5	95-100	3-6 weeks	14	Mangostin	13	85-90	2-4 weeks
5	Tomato	10-12	90-95	2-5 weeks	15	Durian	6	85-90	5-8 weeks
6	Mustard	5	98-100	2-4 weeks	16	Banana	14-16	90-95	1-4 weeks
7	Carrot	5	98-100	3-6 weeks	17	Grape	5	90-95	2-8 weeks
8	Paprika	7-10	95-98	2-3 weeks	18	Jack fruit	12,5	85-90	2-4 weeks
9	Onion	5	65-70	1-8 months	19	Melon	10	85-90	3-4 weeks

10	Garlic	5	65-70	6-7 months	20	Papaya	10-13	85-90	1-3 weeks
					21	Pineapple	7-12,5	85-90	2-4 weeks

4.3. Cost Calculation

Cost was analysed using life cycle cost (LCC) methods to obtain cost per cycle operation. Figure 4 shows the cost of the cold chain in one operation, and also calculation of the escalation cost per year until 12 years (depend on average the life time of the cold chain components)

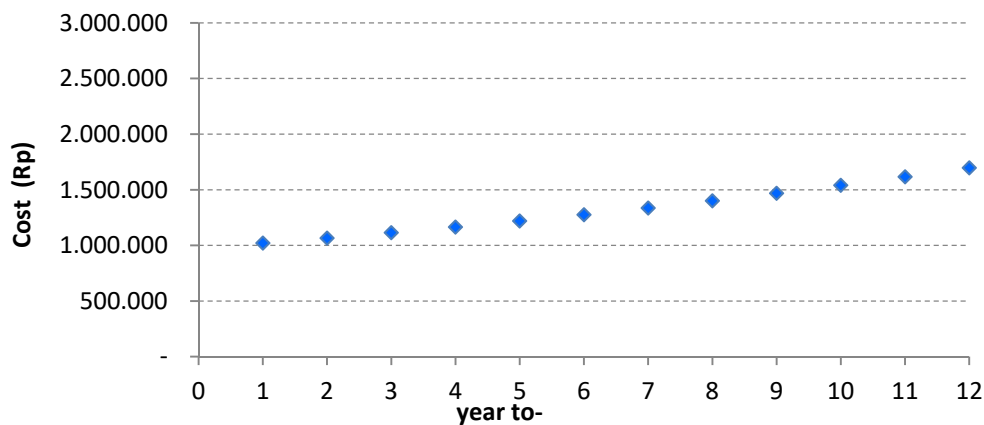


Figure 3. Cost per cycle from year -1 to year -12

It can be seen that cost per cycle of cold chain process about IDR 1.000.000 with linear escalation every year until 12 years will reach around IDR 1.600.000. It can be argued that additional cost of the cold chain application is enough cheap, with the model capacity of product is 1000 kg.

5. Conclusions

Model show effective cold chain to be implemented in Bali Province. The vegetables and fruits product need minimum 5°C temperature and the highest until 16°C so the cold chain components will design operate in medium temperature. Cost of a cycle of cold chain operation show only spend around 1.000.000 IDR and the capacity of the product to be distribute around 1 ton (1000 kg) . It can be concluded that the additional cost per kg is around 1000 IDR per kg. This price (or 0.07 USD) is totally cheap with the much better products quality. Finally, the cold chain is very eligible to be application in Bali Province.

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