ENVIRONMENTAL IMPACT ASSESSMENT OF COATING FRESH-CUT PAPAYA CV. HOLLAND WITH CHITOSAN

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Abstract- This research was aimed to study coating of fresh-cut papaya cv. "Holland" with chitosan solutions (0.5%, 1.0%, 1.5% and 2%). The 2% chitosan solution was the most appropriate concentration to preserve the qualities of fresh-cut papaya. The life cycle assessment (LCA) technique was used to identify 2% chitosan solution for coating fresh-cut papaya using the SimaPro 7.0's software, with the CML 2 Baseline 2000 method. The results showed that highest environmental impact of 2% chitosan solution for coating fresh-cut papaya occurred during the production. The main environmental impacts were marine aquatic ecotoxicity, global warming and human toxicity, respectively. An essential factor which caused these impacts was the usage of electricity during production process.

Index Terms- Chitosan, Environmental Impact Assessment, Life cycle assessment, Papaya.

I. INTRODUCTION

Papaya (Carica papaya cv. '*Holland*') is a rich source of bioactive compounds with high antioxidant activity. However, because ripe papaya is eaten peeled, seeded, cut in wedges and served alone or as fruit salad, it rapidly loses its freshness.

Minimal processing alters the integrity of the fruit and induces surface damage which increases tissue respiration rate and detrimental biochemical changes such as development of off flavors and texture breakdown. Furthermore, microbial contamination of the flesh can occur from the surface, increasing fruit spoilage.

Edible coatings can be a cost-effective alternative to modified atmosphere packaging [1] because they help to prevent physical damage, enhance appearance, and reduce microbial growths [2]. Generally, edible coatings consist of a film-forming biopolymer that carries a functional ingredient (flavors, antioxidants, antimicrobials).

Among the common biopolymeric film-forming compounds, chitosan is a cationic polysaccharide obtained by deacetylation of chitin, the major constituent of the exoskeleton of crustaceans. The cationic properties of chitosan offer the film-maker an opportunity to take advantage of electrostatic interactions with anionic, partially demethylated pectins. In addition, the antimicrobial activity of chitosan against a range of foodborne filamentous fungi, yeast, and bacteria has attracted attention as a preservative of natural origin.

Life cycle assessment (LCA) is a tool for the quantitative assessment of material, energy and environmental impacts of products, service and process [3]. LCA is a methodology for evaluating the environmental load of processes and products (goods and services) during their life cycle (i.e., from "cradle to grave") from raw material acquisition, processing, manufacturing, use and disposal.

The concept of life cycle studies had focused on the quantification of energy and materials used and wastes released into the environment throughout the life cycle. LCA is a methodology used in this study was based on the International standards (ISO) of series ISO 14040 framework [3] and ISO 14044, which provide principles and methodological requirements [4]. The methodology for conducting life cycle assessment commonly considers of four stages: goal and scope definition, life cycle inventory analysis (LCI), life cycle impact assessment (LCIA), and life cycle interpretation as shown in Fig. 1.

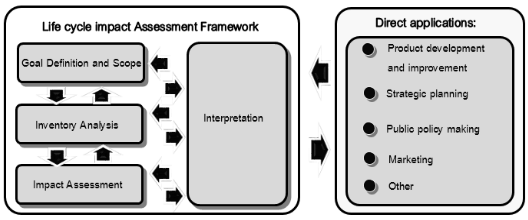

Fig.1.Stages of an LCA (ISO, 2006a)

Firstly, the goal and scope definition establishes the functional unit (FU), audiences, and system boundaries. Defining the functional unit enables the association of the inputs and outputs of the system to a particular reference unit. This phase includes a proper definition of the system under study and its limits, along with the need for data collection, the objective and the level of depth undertaken in the study. Secondly, the life cycle inventory analysis (LCI) is a technical process that deals with the collection and synthesis of information on material and energy flows in various stages of the products lifecycle. Energy and raw material consumptions are considered as inputs; emissions to air, water, and soil, solid wastes, and products as out-puts. This phase includes calculating both the material and the energy input and output of a building system. Thirdly, the life cycle impact assessment (LCIA) phase evaluates potential environmental impacts of various flows of material and energy and assigns to different environmental impact categories. The characterization factor is used to calculate the contribution of the constituents for different environmental indicators (Global warming, Ozone layer, Depletion, Human toxicity etc.) This phase consists of three mandatory elements: selection of impact categories, assignment of life cycle inventory analysis results (classifications) and modeling category indicators (characterization). Finally, the last stage of ISO 14040 is the life cycle interpretation, dealing with the interpretation of results from both the life cycle inventory analysis and life cycle impact assessment. This stage identifies significant issues and the evaluation of results of LCA according to ISO 14040.

The purpose of this research was aimed to find the appropriate chitosan concentration for coating fresh-cut papaya based on its qualities, and then use the LCA technique to identify the environmental impact of using the selected chitosan concentration for coating fresh-cut papaya. The highest environmental impact and its causes were identified for coating fresh-cut papaya.

II. DETAILS EXPERIMENTAL

A. Sample preparation

Papayas (Carica papaya cv. '*Holland*') were purchased at a local market and maintained at 25 ºC until processing. Fruits were uniform in size, peel coloration and 10 ºBrix.

B. Papaya processing and coating

Whole papayas were immersed in sodium hypochlorite solution (150 ppm) for 1 min, washed with potable water, and dried with absorbent paper. All the utensils were also sanitized. Clean fruits were peeled manually, seeded, and cut into 2x2x2 cm^2. Edible coatings used in minimally processed fresh-cut papaya were chitosan at various concentrations of 0% (control), 0.5%, 1%, 1.5% and 2%, respectively. Fresh-cut papaya were dipped into the coating solution for 2 min, then packed in polypropylene (PP) and stored at 5±2°C for 15 days (~10 samples). After that firmness, weight loss, total soluble solids (TSS), color (L*, a*, b*), pH, and titratable acidity (TA) of the samples were analyzed. The appropriate concentration of chitosan solution was then selected for coating fresh-cut papaya.

C. Life cycle assessment (LCA)

This study was aimed to use LCA technique to identify fresh-cut papaya. The environmental performance of 2% chitosan solution. The SimaPro 7.0 software, with the CML 2 Baseline 2000 Version 2.03 was used to analyze and summarize the environmental impact assessment, as well as the main environmental impacts of 2% chitosan solutions. The results from this process simulation were subsequently used as inputs for life cycle inventory. LCA quantifies the potential environmental impact of all production processes, beginning with the extraction of raw materials to the manufacture, use and disposal of the product i.e., from cradle to grave. LCA includes four stages (ISO, 2006a): (i) the selection of goal and scope, (ii) the determination and evaluation of inventory, (iii) the assessment of environmental impact according to inventory results, and (iv) the interpretation analysis of the results.

(i) *Goal and scope definition.*Inthe first LCA phase, scope and goal can be established on the analysis and understanding of a product's life cycle. The goal of this study was aimed to use LCA technique to compare environmental performance of 2% chitosan solution for coating fresh-cut papaya.

(ii) *Inventory analysis.* In the second LCA phase, inventory analysis involves the collection and compilation of the data required to quantify all of the relevant inputs and outputs associated with the production of the functional unit (FU). In this study, the environmental load in terms of materials and energy used during coating fresh-cut papaya with the chitosan solution was estimated. The results from this process simulation were then used as inputs for inventory analysis. Figure 2 show the information related to the materials and energy used as well as the waste generated in producing 1 kg of chitosan solutions.

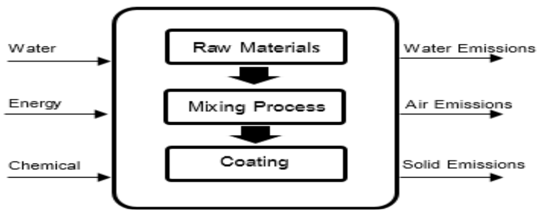

Fig.2. The system boundary of coating fresh-cut papaya with chitosan.

(iii) *Impact assessment.*Inthe third LCA phase, impact assessment converts the environmental input and output data from the inventory phase into their contributions to a range of environmental impact categories. The assessment used the SimaPro 7.0 software, with the CML 2 Baseline 2000 Version 2.03 methodology and complemented its ten impact categories and unit-equivalents. The ten CML 2 Baseline 2000 categories were abiotic depletion (ADP), global warming (GWP 100), ozone layer depletion (ODP), human toxicity (HTP), fresh water aquatic ecotoxicity (FAETP), marine aquatic ecotoxicity (MAETP), terrestrial ecotoxicity (TETP), photochemical oxidation (POCP), acidification (AP), and eutrophication (EP).

(iv) *Interpretation.*The last phase of the process is the interpretation of the results obtained. By using this systematic technique, information from the previous stages was identified, quantified, and evaluated. The final purpose of LCA was to draw conclusions and recommendations useful for decision making. Significant environmental issues were identified for conclusions and recommendations, which should be consistent with the goal and scope of the study by comparing the environmental impact of chitosan solutions for coating fresh-cut papaya.

III. RESULTS AND DISCUSSION

A. Coating papaya

Coating materials in this study were chitosan solutions at various concentrations of 0% (control), 0.5%, 1%, 1.5% and 2%, respectively. The fresh-cut papaya were packed in polypropylene, and kept at 5±2°C for 15 days. The results showed that coating fresh-cut papaya with chitosan at the concentration of 2% was the best treatment to maintain the qualities of fresh-cut papaya compared to coating fresh-cut papaya with other concentrations and non-coating fresh-cut papaya because it delayed changes in color (L*, a*, b*), reduced weight loss, maintained firmness and pH, as well as delayed an increase of (TSS) and titratable acidity (TA) as shown in Figures 3-10.

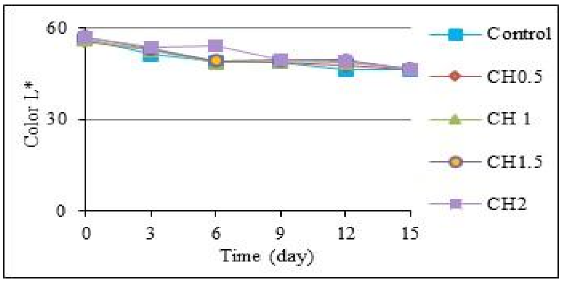

Fig.3. Effect of different concentrations of chitosan solution coatings on the color L* values of fresh-cut papaya during storage at 5±2°C for 15 days.

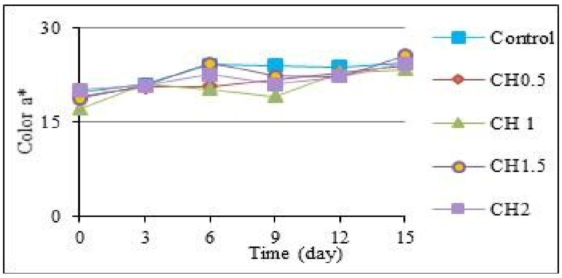

Fig. 4. Effect of different concentrations of chitosan solution coatings on the color a*values of fresh-cut papaya during storage at 5±2°C for 15 days.

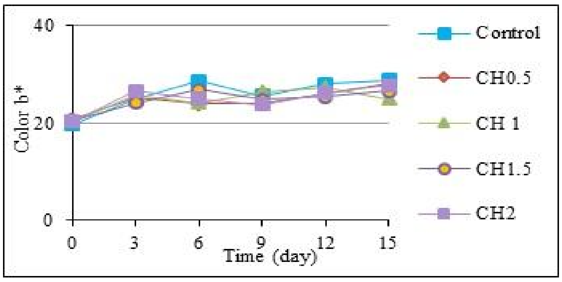

Fig.5. Effect of different concentrations of chitosan solution coatings on the color b*values of fresh-cut papaya during storage at 5±2°C for 15 days.

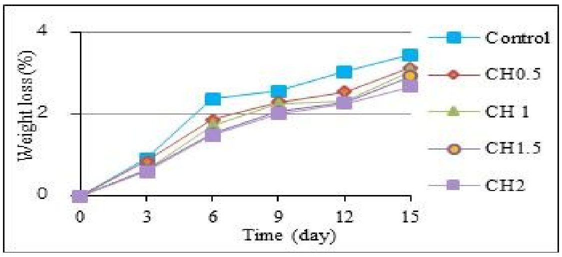

Fig.6. Effect of different concentrations of chitosan solution coatings on the weight loss values of fresh-cut papaya during storage at 5±2°C for 15 days.

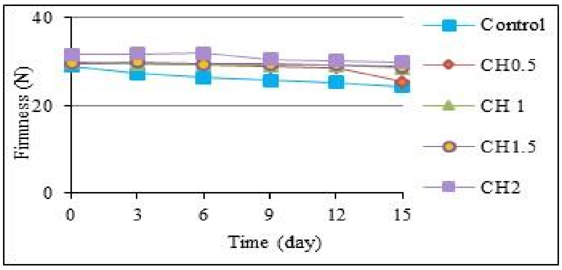

Fig.7. Effect of different concentrations of chitosan solution coatings on the firmness values of fresh-cut papaya during storage at 5±2°C for 15 days.

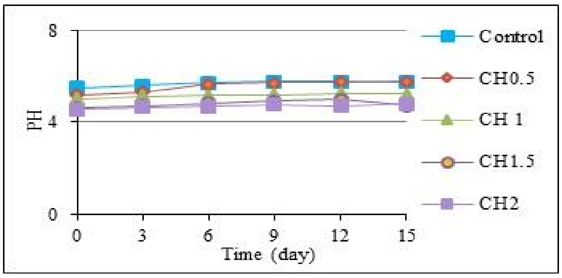

Fig.8. Effect of different concentrations of chitosan solution coatings on the pH values of fresh-cut papaya during storage at 5±2°C for 15 days.

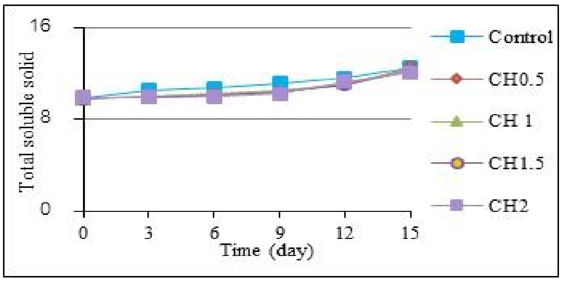

Fig.9. Effect of different concentrations of chitosan solution coatings on the TSS values of fresh-cut papaya during storage at 5±2°C for 15 days.

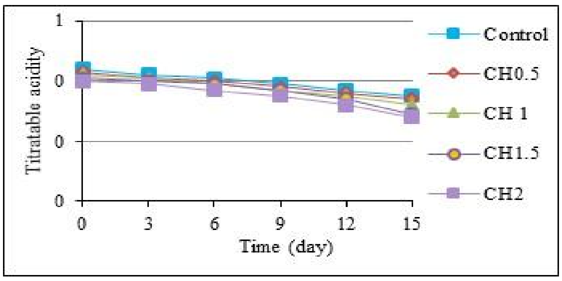

Fig.10. Effect of different concentrations of chitosan solution coatings on the TA values of fresh-cut papaya during storage at 5±2°C for 15 days.

B. Life cycle assessment (LCA)

The environmental performance of 2% chitosan solution for coating fresh-cut papaya showed that the magnitude of potential impacts were: Abiotic Depletion Potential (ADP) 0.008 kg Sb equivalent, Global Warming Potential (GWP100) 0.664 kg CO_2 equivalent, Human Toxicity Potential (HTP) 0.094 kg 1,4 dichlorobenzene equivalent, , Freshwater Toxicity Potential (FAETP) 0.019 kg 1,4 dichlorobenzene equivalent, Marine Toxicity Potential (MAETP) 126.592 kg 1,4 dichlorobenzene equivalent, Terrestrial Toxicity Potential (TETP) 0.001 kg 1,4 dichlorobenzene equivalent, and acidification Potential (AP) 0.007 kg SO_2 equivalent as shown in Table 1. From the analysis results during the raw materials preparation, mixing process and coatingprocess, the highest environmental impact of chitosan solutions occurred during the production as shown in Figure 11. The main environmental impacts were marine aquatic ecotoxicity, global warming and, human toxicity respectively. An essential factor which caused these impacts was the usage of electricity during production process.

Table 1: Quantity environmental impact assessment of coating fresh-cut papaya with 2% chitosan

Impact category	Unit equivalent	2% chitosan
1.Abiotic depletion (ADP)	kg Sb	0.008
2.Global warming (GWP 100)	kg CO_2	0.664
3.Ozone layer depletion (ODP)	kg CFC-11	0.000
4.Human toxicity (HTP)	kg 1,4 DB	0.094
5.Fresh water aquatic ecotoxicity (FAETP)	kg 1,4 DB	0.019
6.Marine aquatic ecotoxicity (MAETP)	kg 1,4 DB	126.592
7.Terrestrial ecotoxicity (TETP)	kg 1,4 DB	0.001
8.Photochemical oxidation (POCP)	kg C_2H_4	0.001
9.Acidification (AP)	kg SO_2 eq	0.007
10.Eutrophication (EP)	kg PO_4 eq	0.000

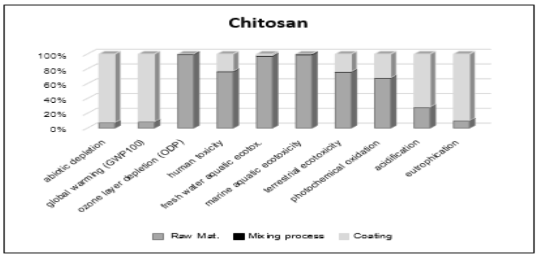

Fig.11.Identification of impacts in the production and coating stage of 2% chitosan solution.

CONCLUSIONS

From this research, 2% chitosan solution was selected for coating fresh-cut papaya since it could preserve the quatities of fresh-cut papaya. From the LCA analysis of coating fresh-cut papaya with 2% chitosan solution, the highest impact occurred during the production. The main environmental impacts were marine aquatic ecotoxicity, global warming and human toxicity, respectively. An essential factor which caused these impacts was the usage of electricity during production process.

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REFERENCES

[1] C. A. Campos, L. N. Gerschenson, and S.K. Flores, "Development of edible films and coatings with antimicrobial activity," Food Bioprocess Technology, vol. 4, pp. 849-875, 2011

[2] L. R. Franssen, and J. M. Krochta, "Edible coatings containing natural antimicrobials for processed foods," In S. Roller (Ed.), Natural antimicrobials for the minimal processing of foods, pp. 250-262, 2003.

[3] International Organization for Standardization, ISO 14040: Environmental management-Life Cycle Assessment-Principle and framwork.2006a

[4] International Organization for Standardization, ISO 14044: Environmental management-Life cycle assessment-Requirements and guidelines.2006b

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