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Exploring Healthy Alternatives to Snacking: Vegetable Chips

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Agricultural & Biological ENGINEERING

CAPSTONE/DESIGN EXPERIENCE 2016

Objective

Potato chips are a cheap yet popular snack across continents. For students living on and around campus here at Purdue, potato chips could prove to be quite a market for producers and convenience for the consumers. However for the project to be profitable, efficiency needs to be evaluated on aspects of operation cost, potential byproduct revenue, product quality and others. This project aims to identify and evaluate such aspects and present a methodology for producing profitable chip products for local consumers.

Introduction

Frying chips is a very commonly seen commercial process. It is safe to assume that fried chips are consumed every minute of the day by people everywhere looking for an easy, cheap, and flavorful snack. That is why we chose to create an innovative chip that resembles the most profitable food product, the potato chip. Our innovation lies in changing the vegetable from potato to other healthier vegetables in order to target a more health-conscious audience that our product can reach. In this report we outline the basic background research, experimentation, and analysis of the potato chip in order to mimic a similar process with our innovative product.

Materials & Method

1. **Peeling** – The peeling process contributes by far the largest quantity of waste to the plant (Pailthrop 759). The potatoes that we will be using for the chips will be left unpeeled, resulting in the chips being healthier since the peels contain an extensive amount of nutritional value.
2. **Slicing and Washing** – To minimize the amount of waste and water used in this process, when the potatoes enter this process they are primarily washed thoroughly using a steam operation to clean and remove the dirt from them. Steam blanching requires significantly less energy than water bath blanching and this is the reason we switched our method.
3. **Blanching** – The steam coming from the washing water will be recycled and will be kept frequently warmed, approximately 200-2120F ("Improving Environmental Performance at a Potato Chip Plant in Kazakhstan"), this will reduce bacterial growth and any possibility of any contamination of the final potato chip product. The water will have to be replaced with fresh water every so often to avoid foaming or unclean water. The wastewater that is used in the exit stream of the blanching process can be screened and then can be pumped back into the spray system for washing, which closely resembles a continuously closed looped system.
4. **Drying** – 200C until moisture content is reduced to 10-20% by weight percentage (from initial 80%+), 145-160 C until further moisture removal to 2% ww. Final oil content should be about 16-25% of product (Dreher et al.). The drying step is a continuation of the cooking/sterilization step where moisture content is further reduced to give the desired texture.
5. **Cooking/Sterilization** – Oiled potato chips (raw) baked at least 200C followed by another period between 145-160C for 4-6 minutes in a fluidized bed using hot forced air or superheated steam (preferred), dried in air. Baking must occur below smoke point of oil (220-230C) to prevent flavor changes due to oil degradation (Dreher et al.). This two-staged process is to ensure the 12-D reduction of Clostridium Botulinum, a deadly microorganism, in potatoes. Doing this process will also give desired texture to the potato, which is needed.
6. **Seasoning** – The ingredients need to be properly mixed to ensure the components to avoid overpowering of certain flavors and to achieve a good balance.

Flavoring ingredients;

fajita seasoning (Yummly), 1 tbsp cornstarch , 2tsps chili powder , 1 tsp salt, 1 tsp paprika, 1 tsp sugar, ¾ tsp curry powder, ½ tsp onion powder, ¼ tsp garlic powder, ¼ tsp cayenne pepper, and ¼ tsp cumin

Item	Percent cost (%)	Cost ($)
Purchased equipment cost	100	51,690.09
Equipment installation	45	23,260.54
Instrumentation and controls	18	9,304.22
Piping	16	8,270.42
Electrical systems	10	5,169.01
Buildings	25	12,922.52
Yard improvements	15	7,753.51
Service facilities	40	20,676.04
Total direct plant cost	269	139,046.35
Engineering and supervision	33	17,057.73
Construction	39	20,159.14
Legal expenses	4	2,067.61
Contractor	17	8,787.32
Contingency	35	18,091.54
Total indirect plan cost	128	66,163.32
Fixed capital investment	397	205,209.66
Working capital	70	36,183.07
Total capital investment	467	241,392.72

Table 1: Economic Implications of Direct Costs (by item).

Results/Data Analysis

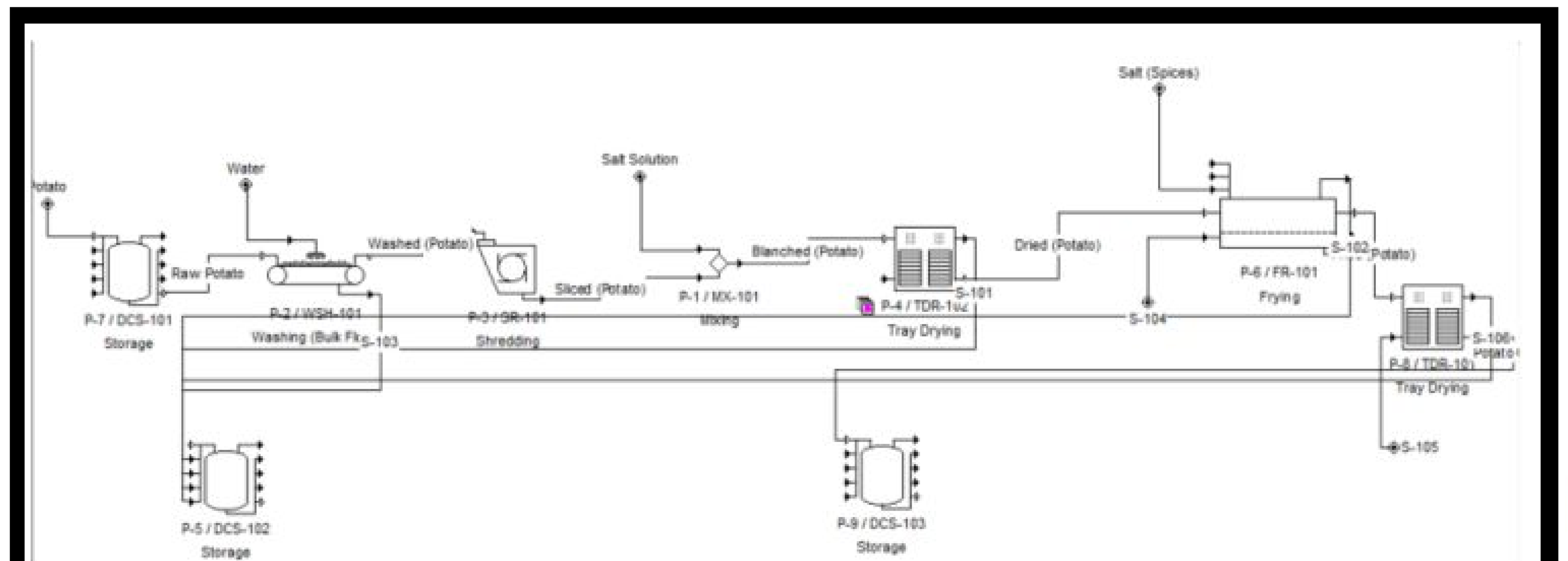

Figure 1. Super Pro Overall process flow diagram of the potato chip product

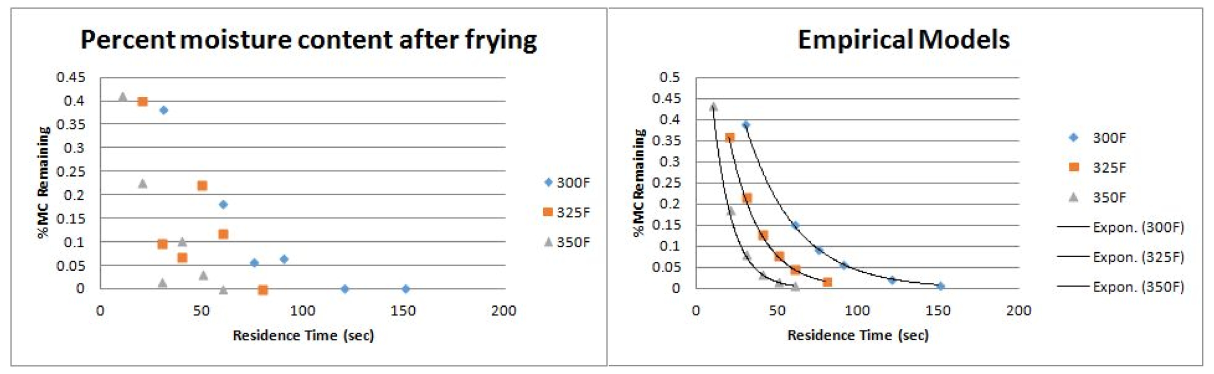

Figure 2. Moisture content loss comparison from frying experiment

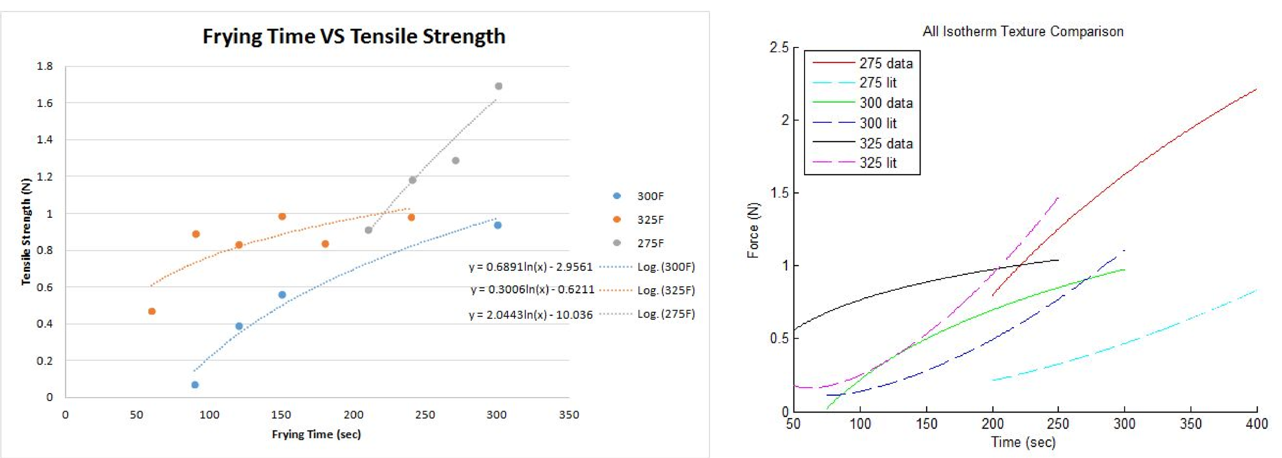

Figure 3. Tensile strength comparison from frying experiment. Error made in some trials where 1N load was fixed.

Sustainability and Optimization

Three unit operations investigated for optimization/sustainability:

- Blanching: Continuous loop blanching system (Figure 6) sustains water and optimizes both the slicing and washing and blanching processes.
- Frying: Steam reutilization via breathable material. Frying oil conversion to biodiesel.
- Drying: Heat pump drying system harnesses recoverable heat from other processes and improves energy efficiency. Useful for products with high initial moisture contents and works best at long hours of operation.

Item	Reference	Min Cost $	Max Cost $
Total Product Cost	n/a	537042.82	4296342.53
Raw material	10-80% TPC	53704.29	3437074.03
Operating labor	10-20% TPC	53704.29	859268.51
Supervisory/clerical labor	10-20% operating labor	5370.429	171853.71
Utilities	10-20% TPC	53704.29	859268.51
Maintenance/repairs	2-10% fixed capital investment	4104.20	20520.97
Operating supplies	0.5-1% fixed capital investment	1026.05	2052.10
Laboratory charges	10-20% of operating labor	5370.429	171853.71
Patents and royalties	0-6% of TPC	0	257780.5518
Local taxes	1-4% of fixed capital investment	2052.10	8208.39
Insurance	0.4-1% of fixed capital investment	820.84	2052.10
Rent	Depends on location		
Financing and interest	0-10% TPC	0	53704.29
Administrative costs	2-5% TPC	10740.86	214817.13
Distribution/marketing	2-20% TPC	10740.86	859268.51
R&D	5% TPC	26852.15	214817.13

Table 2: Economic Implications of Product Costs (by item).

Figure 4. Results from the frying process

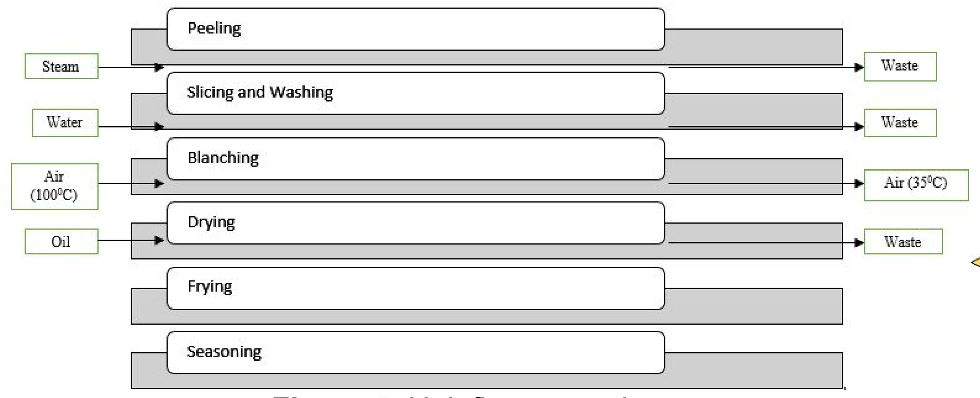

Figure 5. Unit flow operations

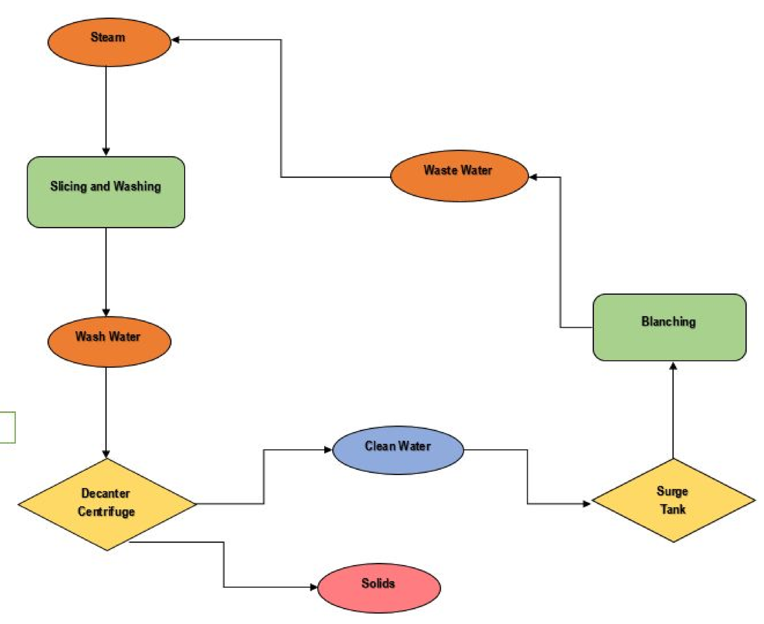

Figure 6. Continuously looped blanching system

Economics

From energy balance on a per potato basis 815 kJ of energy is required for processing; from a simple google search each kWH costs about $0.10. Energy dispensed in temperature change and water phase change constitute 600+ kJ per potato. Biodiesel produced from frying oil typically reaches 80%+ efficiency with NaOH catalyst ($400/ton); Biodiesel was selling at slightly over $2 in 2015. The Chemical Engineering Plan Cost Index was used to help estimate equipment purchase cost, which summed to an estimated $51,690.09. Assuming solid processing plant, total capital investment is estimated to be $241,392.72. The grand total estimate for raw material (potato, oil, bag, salt) cost is $429,634.26, from which total product cost is estimated to range from $537,042.82 to $4,296,342.53 per year. The price per bag of chips will be sold for $1.99 in order to up to par with other brands yet still provide value to the product. Our lower limit for total product cost is about equal in number to our bag production number, which allows us to sell this $1.99 and still make a good amount of profit.

Conclusions/Discussion of Alternatives

Due to equipment limitation, the originally planned two-stage frying was not feasible. In addition, frying temperature and residence time tested were not appropriate and generated difficult results. From Figure 2 it is implied that 1-2 minutes of frying should be desirable at 300F. Not enough data to conclude whether literature statement was right in claiming steady state tensile strength is not a function of temperature.

Review of more literature reveals that drying-coupled frying is an alternative to two-staged frying. Which stage occurs first is up to further investigation. Blanching could be accomplished using either hot water or steam. Considering the latent heat associated with boiling water, hot water might be more easily fueled.

Additionally, a tray dryer was considered, but given the efficiencies of a heat pump drying system, this equipment would be more effective for a large operation. HPD drying when compared to other commonly used dryers out-performed them with a greater drying efficiency, rate, capital and running cost, and operating range and control. Also, HPD systems are best for our product due to its high moisture content.

References

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Above literature does not represent all that contributed to this project. See main report for full list of references

Acknowledgements:
Purdue Agricultural and Biological Engineering Department

Instructor:
Professor Martin Okos

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