The Design of a Tomato Powder Processing Plant with a Capacity of 75,000 Tonnes Per Annum in Oyo State, Nigeria, West Africa

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Abstract

This project designed a plant that will process 250 tonnes of raw tomatoes per day. The duration of this production was spread across 24 hours and operated for 300 days in a year, which gave a yield of 17.5 tons of tomato powder per day. From these specifications, the best process route was synthesized. The process route selected involved choosing and sorting the tomatoes, washing, blanching, blending, spray drying (as the drying process), packaging and labeling. Through a series of investigations, the most feasible way to dry tomato powder on an industrial scale proved to be the spray-drying method because the process was very rapid, required low labor cost, and was relatively simple to operate and sustain. The particle size was also easy to control with this technology, making it easy to correlate with product standards. The equipment to be used was then identified which included the machine vision, a spray washer, a water Blancher, an industrial blender, a spray dryer, and a powder packaging machine. Material and energy balance were evaluated around the whole plant. A process flow diagram and basic piping and instrumentation diagram were also computed using engineering software such as Microsoft Visio. From the previous work done, the selected process unit, the spray dryer, was designed with a detailed piping and instrumentation diagram made around it. The site of the plant was resolved, adjacent oriental foods along the Lagos-Ibadan Expressway. It was necessary to site the plant in an area where raw materials can easily be delivered to. The area selected was directly linked to a major highway, the Lagos-Ibadan Expressway, thereby making transport quite affordable. The site layout alongside the plant layout was constructed. The layouts clearly showed the standard flow process.

Keywords: tomatoes, processing plant, storage of tomatoes, tomato powder production, spray drying.

Introduction

Tomato is a red, edible fruit that has high nutritional value and is versatile in the food industry. However, it spoils easily. It was estimated that about 65% of the tomato produced in Nigeria spoils due to lack of storage (Hayes, Smith, & Morris, 2010).

A feasibility study was carried out on the project and it was concluded that it is technically feasible to construct the plant because the equipment is available, process routes are feasible and process conditions are attainable. The best way to produce the tomato powder on an industrial scale was using the spray drying method. This method was chosen because it was very rapid, required low labor cost was relatively easy to carry out and particle size of the product can easily be controlled.

The site selected for our plant is in the Oluyole local government area in Oyo State, Nigeria. It is going to be adjacent to Oriental Foods Industries Limited. It has an area of 4,000km^2 and a population of 202,725 as of 2006. It shares boundaries with four native governments, Ibadan South West, Ibadan South East, Ona Ara, and Ido ingenious government all within the Ibadan city. The site was selected due to its proximity to the Lagos-Ibadan expressway and the availability of labor and land.

The aims and objectives of the Chemical Engineering design project were to address the challenges that arose as a result of perishable qualities of tomatoes by choosing a process route for a plant for the production of tomato powder processing plant, carrying out a feasibility study to serve as an indicator of the technical and economic viability of the process, design a process plant to produce 75,000 tonnes per annum in Oyo State, Nigeria. The key challenges that we faced by the plant in the processing of tomato powder included tomato price fluctuation and maintenance of product quality. These challenges and others were dealt with by proper project management and maintenance practices.

The varieties of tomatoes available in the market including Dandino, Danyeka, UTC, Roma, Ibadan local, etc. They had different tastes and coloration, and for quality and attractive production, varieties can as well be blended such as Dandino (having the sweetest taste) and UTC (having the brightest deep Red color) (Abdulmalik et al., 2014). The best species of tomatoes that are grown or cultivated in Nigeria are the Roma tomatoes. These acid tomatoes are known for their chewy flesh and relatively low water content, about 93% moisture content, which makes them a good choice for making tomato powder (Jayathunge et al., 2012). Hence, for this design, Roma tomatoes will be our choice in producing tomato powder

The raw tomatoes were obtained from Kano, Taraba, Gombe, Bauchi, Kaduna, Sokoto, Zamfara, Katsina, and Jigawa states. This was administered to keep up with the high capacity needed to be processed per day.

Fig. 1. Roma tomatoes cultivated in Nigeria.

There are a variety of ways to produce tomato powder from raw tomatoes, the main process to be considered to be the dehydration process by which moisture was removed from the tomatoes. The universal routes taken in the production of tomato powder include choosing and sorting the tomato, washing, and blanching. From the blanching process, there are different routes that plants can take to get tomato powder. For some processing plants, after the blanching process, the tomatoes are pulped to remove the solid particles within, then dried to obtain tomato powder (Sylvanus & Victor, 2012). For other processing plants, the tomatoes are sliced after blanching, then dried, after which the dry tomato slices are milled to get tomato powder (Arjenaki, Moghaddam, & Motlagh, 2013).

The process routes taken by 7 senior year Chemical Engineering students in my research group included choosing and sorting the tomatoes, washing, blanching, blending, drying, and then packaging the tomato powder. Blending was picked over pulping so that all the solid particles will contribute to the yield of the tomato powder.

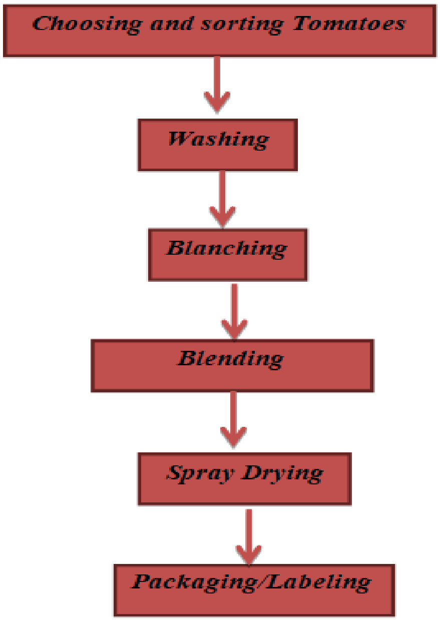


Fig. 2. Selected Process route

Sorting refers to the removal of rotten, damaged, and cracked tomato fruits from healthy, bright, and clean fruits. The raw materials have to be processed as soon as possible (within 48 hours after harvesting) to avoid deterioration. The efficiency and effectiveness of sorting govern the quality standard of the packing lines and the product (Jarimopas & Jaisin, 2008). Consequently, it is imperative to have a swift, coherent, genuine, and vigorous approach for sorting. The machine vision will be used for the sorting process. It is the best technique for quality evaluation and sorting and its use will contribute to the automation of sorting and reduce labor costs and the number of employees required. Among the other advantages of machine vision are non-destructive, accuracy, and consistency. The machinery involved a conveyor, power drive with the inverter, light source, and CCD camera. The software consists of separate algorithms for shape, size, maturity, and defect detection.

After harvesting, the tomato contains mold. These molds are a risk for the tomatoes and need to be removed during the processing. The fruit is emptied into the washer where it is washed and an intensive cleaning result is achieved. Lye solution may also be used in washing tomatoes to remove drosophila eggs and larvae. It was reported that soaking tomatoes in a 0.5% lye solution for 3 min at 130°F (54°C) was effective for this purpose (Maul et al., 2000).

Blanching is simply scalding of vegetables or fruits in hot water or steam to reduce the enzyme action which causes a change in color, texture, and loss of flavor. Blanching cleanses the surface of dirt and organisms, brightens the color, and helps retard the loss of vitamins. A water blancher comprises a pan with inlet and outlet points. At the bottom of the pan are several outlets that are connected to the circulation system. The circulation system distributes the water back to the pan through injectors. The water is boiled by injected steam or by a heat exchanger. According to research and development centers in Anuradhapura, Sri Lanka, hot water blanching of ripe tomatoes at 60°C for one minute is the most effective pre-treatment in the preservation of the red color of the dehydrated product. As a result, this will be the process condition.

Blending is the process where the natural liquid, vitamins, and minerals are extracted from raw fruits. This process strips away any solid matter from the fruit and what is left is liquid only. Blending is important for food manufacturers so that products are the same every time—consistency is key. If a recipe is not blended properly, the taste, texture, color, and appearance of the final product can all be affected. Spray drying is a method of producing a dry powder from a liquid or slurry by rapidly drying with a hot gas (Seltzer & Settelmeyer, 1949). This is the preferred method of drying foods or pharmaceuticals. Air is the heated drying medium (Baker & Mckenzie, 2014). Criteria like the amount of juice, feed flow rate, and the inlet, outlet air temperatures have a vital role in the output of fruit powders. Fruit powder is hygroscopic and requires drying agents (Siddick & Ganesh, 2016). Although the spray drying method has high capital and installation cost, lower thermal efficiency, and products are susceptible to heat degradation, it has the following advantages over other types of drying such as low labor cost, relatively simple operation and maintenance, reduces transport weight of foods, compliance with the product standards, continuous and easy to control the process, applicable to both heat-sensitive and heat resistant materials, satisfies aseptic/hygienic drying conditions (Mujumdar, 2010).

As a result of the above, spray drying has been chosen as the drying method. Conventional spray dryer processes consist of the following three stages such as atomization of feed into the droplet, spray-air contact and drying droplets, product recovery, and final air treatment (Muzaffar, Nayik, & Kumar, 2015).

Fig. 3. Industrial spray dryer

The tomato powder is then packaged, labeled, and boxed to be distributed for distribution. Aluminum foil will be used to package the tomato powder (Sobowale, Olatidoye, Odunmbaku, & Raji, 2012).

Literature Review

[Hayes, Smith, & Morris, (2010)] examined the quality, composition, standards, and requirements for tomato production. They emphasized that the characteristics of importance in tomato production were color, cohesion, and consistency. They saw a lack of uniformity of quality measures. They stated that, while color may be assessed, no color criteria for tomato production are established.

[Abdulmalik et al., (2014)] investigated the degradation of tomatoes after harvesting by farmers to reduce the enormous wastages that occur. They stated that the farmers are compelled to sell at a low price and do not profit from their produce. They proposed canning as a method of storing tomato paste and spray drying as a more efficient method of producing tomato powder. They also discussed the benefits and drawbacks of hot air convective dehydration with milling and refractive window drying.

[Jayathunge et al., (2012)] developed a suitable drying technique for the manufacturing of dehydrated tomato powder and its utilization in food production. Based on the product color and water activity, they calculated the best conditions for producing dehydrated tomato powder. Depending on his findings, it was recommended that appropriate packing materials be used based on requirements such as moisture content, water activity, and rehydration ratio.

[Arjenaki, Moghaddam, & Motlagh, (2013)] explored the necessity to develop an effective machine vision system for tomato sorting. They investigated characteristics such as form, size, maturity, and flaws. They sampled around 210 tomato species and evaluated the pictures of each sample, shape, size, and system precisions were approximately 84.4 %, 90.9 %, 94.5 %, and 90%. They obtained these findings with a single line at a rate of 2517tomatoes/hr.

[Maul et al., (2000)] studied the flavor and aroma of ripe tomatoes kept at several temperatures, including 5°C, 10°C, 12.5°C, and 20°C. It was observed that tomato held below 20°C was judged poorer in mature fragrance, sweetness, and flavor by sensory reviewers and greater in sourness (people trained to evaluate the taste, flavor, and texture of food products). They also observed that tomatoes at 5°C had the least developed aroma and flavor.

[Siddick & Ganesh, (2016)] emphasized the importance of spray drying as a post-harvest method for producing tomato powder with a long shelf life. They investigated the application of spray drying technology for tomato cultivars, concentrating on factors such as feed flow rate, input and output temperature, and the addition of barley dextrin using a spray drier in India.

[Adegbola et al., (2012)] investigated the processing of tomatoes into various products, starting with tomato paste. They addressed the massive waste involved in tomato production owing to the nature of the crop, which renders it very prone to degradation after harvest if not stored properly. They outlined the procedures to be followed in the manufacturing of processed tomatoes, as well as the benefits and challenges of processed tomato and information on processes to be followed for the production of tomato produce They also investigated the issues connected with the packaging of finished tomato products, as well as marketing techniques to raise product awareness. They proposed that the establishment of processing plants by investors would produce money and jobs while also assisting in the reduction of waste in Nigeria.

Methodology

The material balance for each process in the plant was drawn up. After then, the energy balance was also carried out. The process flow diagram for the plant was then drawn up using Microsoft Visio. Microsoft Visio was picked because the software has a user-friendly interface. It also has general, flexible drawing tools to accommodate the needs of the user.

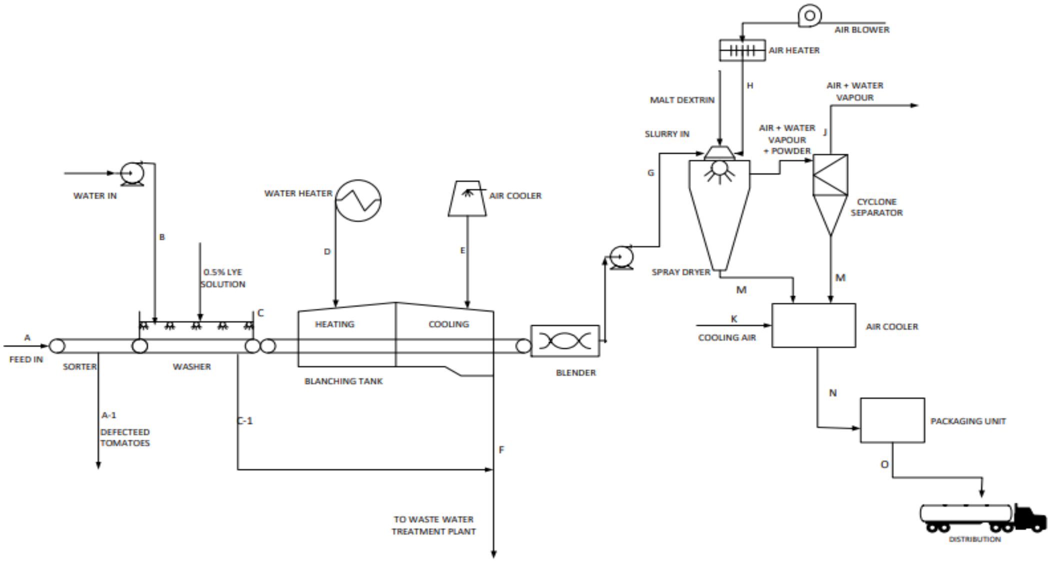


Fig. 4. Process flow diagram of tomato powder processing plant.

The engineering design of the spray dryer involves chemical engineering design as well as mechanical engineering design. The chemical engineering design involves considering the sections that make up the spray dryer and how each section operates. The mechanical engineering design, on the other hand, involves the design of the spray dryer as it is a pressure vessel, specifying the basic design information. The spray dryer is made up of 5 major components namely the drying chamber, hot air supply system, feed supply system, atomizing device, and powder recovery cyclone.

The spray drying chambers are typically field fabricated. They are built on the ground in two sections, the chamber, and the cone, and then a set of structural steel by cranes.

Assuming the vessel has a residence time of 1 minute (60secs). From the Process Flow Diagram, the airflow rate is 3000 m3/hr = 29.4 cfs.

Dryer Volume, Vd = 29.4 * 60 = 1,764 Cu ft

Assuming the straight sides of the vessel is 4 times the diameter and that the vessel has a 600 cone,

1764 = 4D [22D2/7(4)] + 0.866(22) D3/7(12) = 3.3684D3

Therefore, D3 = 523.69

The diameter of the vessel = 8ft

Many factors have to be considered when selecting engineering materials, but for a chemical process plant, the overriding considerations are usually high temperature, strength, and the ability to resist corrosion. Stainless steel is classified as the best choice for the construction of spray dryer for the tomato powder production process due to various advantages it has properties over other construction materials. Properties such as high corrosion resistance, good elasticity modulus, ease of fabrication, available in standard sizes and favorable relative costing rate. To impart corrosion resistance, the chromium content must be above 12%, and the higher the chromium content, the more resistant the alloy to corrosion in oxidizing conditions. Nickel is added to enhance corrosion defiance in non-oxidizing environments.

The hot air will be passed in a co-current manner which implies the same direction as the sprayed liquid atomizer. With the co-current flow, particles spend less time in the system and the particle separator. This flow generally allows the system to operate more efficiently. In this sequence, the atomized blobs penetrating the dryer are in touch with the hot inlet air, but the temperature is kept below due to an increased proportion of evaporation taking place and much at the wet-bulb temperature. It also consists of four main parts namely; supply fan, air filters, air heaters, air dispensers.

The feed supply system has a flowrate of 9,896Kg/hr, a temperature of 35°C, and a pressure of 1.0132Bar. The rotary atomizer considered the most flexible atomizing device is suitable for a wide range of products. The rotary atomizer is suitable for an extensive range of products. Rotary atomizers produce a thin particle size dispersion and circulation of powder. They are preferred because they handle high feed rates without clogging; formation of uniform size particles, low-pressure operation; high efficiency. They can operate at low pressure than that required in hydraulic and pneumatic nozzle atomizers.

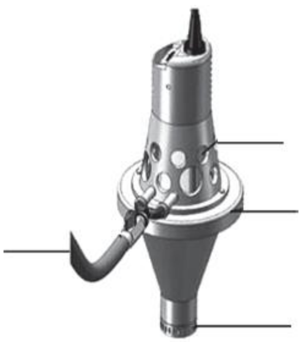


Fig. 5. Rotary atomizer

The type of equipment to be used is a **cyclone with a tangential entry.** These types of cyclones have a distinctive and easily recognized form and are widely used in food processing industries. In the agricultural processing industry, 2D2D cyclone designs are the most commonly used abatement devices for particulate matter control.

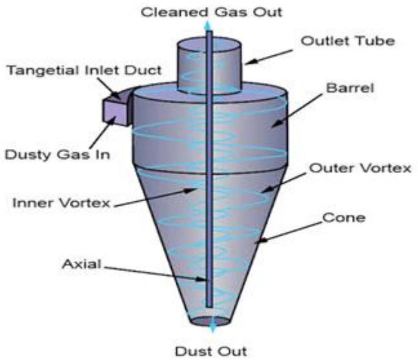
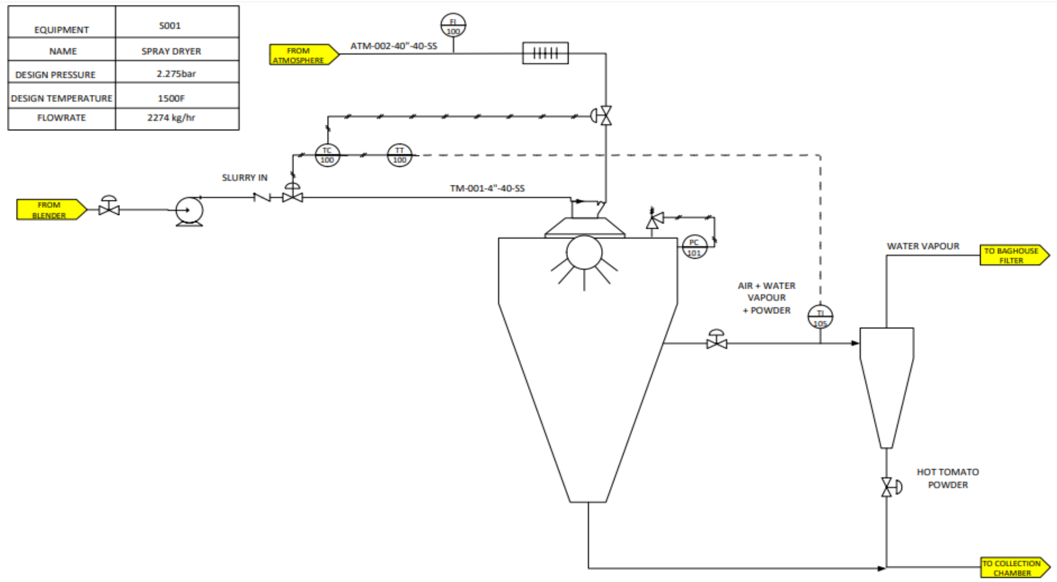


Fig. 6. Cyclone with a tangential entry

The piping and instrumentation diagram (P&ID) for the whole plant was done first, followed by a detailed one for the spray dryer. The P&ID was drawn up using Microsoft Visio.



EQUIPMENT	S001
NAME	SPRAY DRYER
DESIGN PRESSURE	2.275bar
DESIGN TEMPERATURE	1500F
FLOWRATE	2274 kg/hr

Fig. 7. Piping and instrumentation diagram of spray dryer

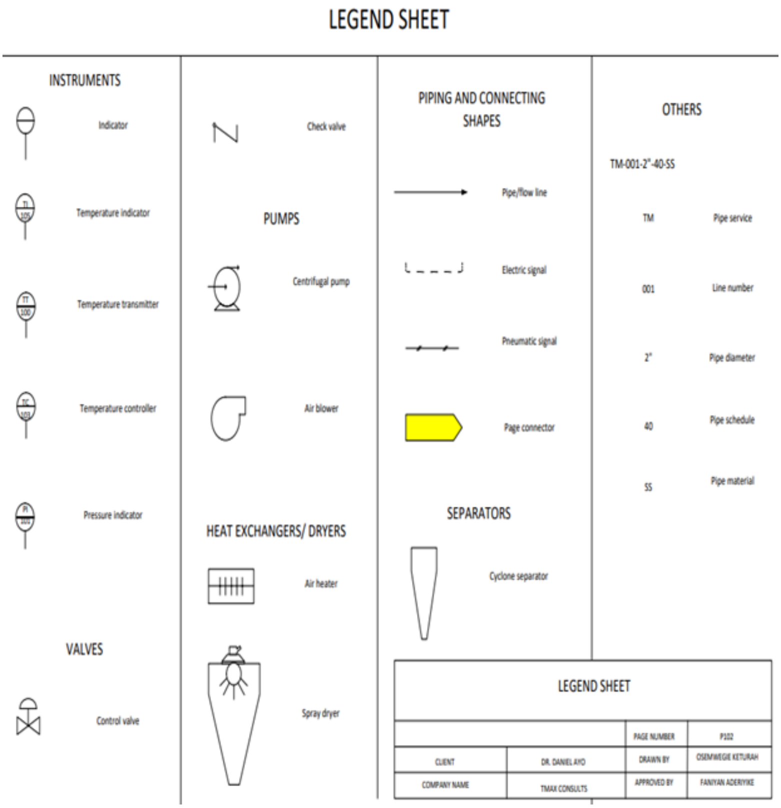


Fig. 8. Legend sheet of elements in P&ID of the spray dryer

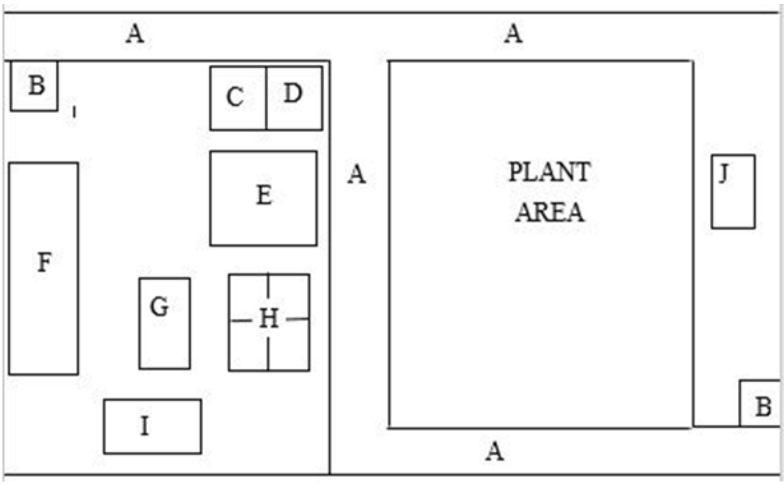


Fig. 9. Site layout

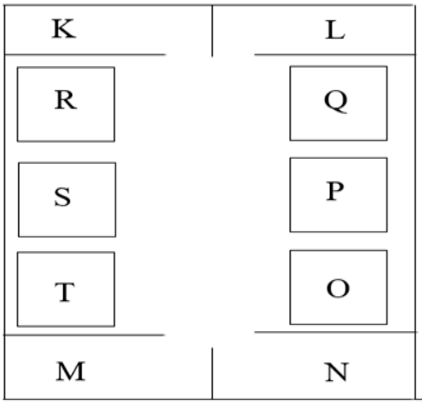


Fig. 10. Plant layout

LEGEND

A – ROADS	K – CONTROL ROOM
B – SECURITY	L – QUALITY CONTROL LAB
C – MAINTENANCE WORKSHOP	M – RECEPTION OF TOMATOES
D – BOILER	N – WEIGHING OF TOMATOES
E – STOREHOUSE	O – CHOOSING & SORTING
F – ADMINISTRATIVE OFFICE	P – WASHING
G – CANTEEN	Q – BLANCHING
H – MALE/FEMALE CHANGING ROOM & TOILET	R – BLENDING
I – CLINIC	S – SPRAY DRYING
J – TRUCK CAR PARK	T – PACKAGING & LABELLING

Fig. 11. Legend sheet showing the representation of each figure in site & plant layout

Roads: If a site is flat, the topography may not influence the location and layout of the building, but on a sloping site, the topography is likely to be a significant factor. The configuration of the road linking where the plant is located (Oluyole LG) opposite Oriental food industrial limited is a flat surface with no slope, which enables easy road access from the main gate to the expressway.

Security: The security building is positioned at the entrance of the gate facing an east flat surface side to have reduced sunlight by day and to have easy access to what is visible to the surrounding. It is also important to monitor the goings of workers and products.

Maintenance workshop: The distance between where this department is located and where the plant area building is situated is for easy repair, correction, and maintenance of faulty or damaged parts in the spray dryer and other utilities in the work area.

Storehouse: This is a building where the final product is stored. It is located close to the plant area because of the easy movement of products from the point of production to the warehouse.

Administrative office: A rule of thumb applies to this which is "minimize the use of highly visible large retaining walls." If they are over a meter, they should be stepped and landscaped.

Canteen: In a site layout, this building is usually close to the administrative block and the clinic. A consideration in site layout is that the cafeteria should not be far from the clinic.

Discussion

The site selected for our plant is in the Oluyole local government area in Oyo State, Nigeria. It is going to be adjacent to Oriental Foods Industries Limited. It has an area of 4,000km^2 and a population of 202,725 as of 2006. It shares boundaries with four native governments, Ibadan South West, Ibadan South East, Ona Ara, and Ido ingenious government all within the Ibadan city. The Urban segment of the native government constitutes the Lagos/Ibadan Express Road, Old Lagos Road, and New Garage, where giant companies were situated. Companies like; British America Tobacco (BAT), ROM Oil, Black-Hors plastic company, Jubaili Agro-Limited, KAMAR industries. The populaces in Oluyole local government are farmers with arable soil for crops like cocoa, cashews, orange, mango, etc.

The site was selected due to its proximity to the Lagos-Ibadan expressway and the availability of labor and land. It is approximately 150km from Lagos by the most direct route and 659km from Abuja, the Federal Capital Territory (FCT). It has a well-developed road network.

The economic construction and efficient operation of a processing unit will depend on how well the plant and equipment specified on the process flowsheet are laid out and the following are the factors that affected the site selection of the tomato powder production plant in the Oluyole local government in Oyo State:

Availability of raw materials: Unrestricted and regular supply of raw materials from Kaduna or Kano State. Since tomatoes are weight loss and cannot be preserved for a long time, adequate transport facilities are ensured to supply the raw materials.

Transport facilities: The transport of raw materials and products to and from the plant is also a major factor. The site being located in Ibadan makes road transportation easier, and road transportation will be majorly used for conveying raw materials and finished products. Air transport is considered for the movement of personnel and equipment.

Availability of labor: Labor will be needed for the construction of the plant and its operation. For a location like Ibadan, there is an adequate pool of unskilled labor available locally and labor suitable for training to operate the plant.

Utilities (services): The plant is located near a source of water of suitable quality. The process water can be drawn from a well. There is also a cheap source of power supply and a relatively affordable source of fuel.

Nearness to Market: Market changes influence the enterprise of a manufacturing unit. The site, located in Ibadan is near markets like Ogun and Lagos, which is the center of commerce. Tomato powder is also highly needed in Lagos because of its high shelf life compared to raw tomatoes and tomato paste.

Environmental impact and effluent disposal: All industrial processes produce waste products, and full consideration must be given to the cost of disposal. The disposal of toxic and harmful effluents will be covered by local regulations, and the appropriate authorities must be consulted during the initial site survey to determine the standards that must be met. The environmental laws guiding Oluyole, Ibadan is the same as the ones guiding Nigeria.

Soil, climate, and topography: The climate conditions of Ibadan are stable to set up an industrial plant and to help workers to be efficient. Ibadan is not subject to adverse climatic conditions such as earthquakes; hence it is favorable to set up a site. The Oluyole area in Ibadan has a good topography (its plain land, it's not hilly) which makes it suitable for industries. Oluyole, Ibadan area has sufficient suitable land available for the proposed plant and future expansion. The land is flat, well-drained, and has suitable load-bearing characteristics.

Government, policies, and regulations: Industrial Development and Regulation Act of 1951 laid down certain rules, regulations, and formalities to be complied with before setting up an industrial unit. Prior permission and license are necessary under this act before setting up a new industrial unit. All these will be taken into considerations and necessary procedures will be followed before setting up the plant at Oluyole, Ibadan.

Local community considerations: The intended plant must be satisfactory to the residents of the Oluwole local government. Safety measures are mandatory in the positioning of the plant, so it doesn't serve as a threat to the lives and properties of communities within the vicinity. Plant proximity brings about productivity and resources to the community. The traditional institution of Oluyole Local Government comprises the Baale which is under the control of Olubadan of Ibadan Land. There is a strong attachment between the traditional rulers and other elders in their community. As a result, community conflict is very unlikely after the plant begins operations. The corporate social responsibility of the industry to the community will be duly performed.

Nearness to adequate banking and credit facilities: For the productive management of the business, banks should be located in the community to offer services to the people, which creates economic growth. Nearness to banks and financial institutions is an important consideration for the location of an industrial unit.

Maintenance: Equipment that requires dismantling for maintenance, such as compressors and large pumps around the spray dryer unit, should be placed undercover.

Safety: Blast walls may be needed to isolate potentially hazardous equipment and confine the effects of an explosion. At least two escape routes for operators must be provided for each level in process buildings (Esguerra, Rolle, & Rapusas, 2013).

Plant expansion: Equipment should be located so that it can be conveniently tied in with any future expansion of the process.

RECOMMENDATION

Tomatoes are a highly nutritious food ingredient used by all Nigerian tribes in the preparation of numerous foods. Its strong demand has made it a very profitable business for individuals, and it is this business that ensures a good return on investment.

Given the inadequacy of local tomato powder processing facilities, I recommend resources be made available for the fabrication and construction of tomato processing facilities. Executing this will help barely noticed tomato products supplied locally to attract foreign currency income and promote domestic food sufficiency.

There needs to be a greater emphasis on tomato processing in Nigeria due to the increase in the quality of life in cities and the rapid urbanization of rural areas, which contributes to high export potential and a positive return on investment.

The lack of storage and processing facilities and under-developed marketing channels resulted in 50% of tomato production is destroyed. Converting tomato to powder will reduce the high percentage of tomato that generally rots away, and investors can benefit from trade liberalization in West Africa (ECOWAS) to commercialize their products.

Conclusion

The production of tomato powder will respond to the challenge of tomato deterioration in Oyo State and elsewhere. This measure was intended to reduce the deterioration of tomatoes in Nigeria and to reduce the import of processed tomato products.

Through a series of investigations, the most feasible way to dry Tomato powder on an industrial scale proved to be the spray-drying method because the process was very rapid, required low labor cost, and was relatively simple to operate and sustain.

Based on the results obtained during the design of the plant, it was recommended that investments be made for the establishment of this plant. More investment should be made in growing raw tomatoes, which will help reduce the cost of raw tomato material (Adegbola et al., 2012).

The feasibility study carried out indicated that it is technically feasible to construct the plant because the equipment is available, the process route is feasible, and the process conditions are attainable. It was shown from the safety analysis that the safety operability concerns of the plant can be taken care of by proper engineering control, environmental control, and personal protection.

In addition, the economic analysis shows that the plant is profitable.

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References

[1] B. Jarimopas & N. Jaisin. (2008). “An experimental machine vision system for sorting sweet tamarind,” *J. Food Eng.*, vol. 89, no. 3, pp. 291–297. DOI: 10.1016/j.jfoodeng.2008.05.007.

[2] C. G. J. Baker & K. A. Mckenzie. (2014). “Drying Technology : An Energy Consumption of Industrial Spray Dryers,” no. October, pp. 37–41. DOI: 10.1081/DRT-200047665.

[3] E. B. Esguerra, R. Rolle, & R. S. Rapusas. (2013). “Post-harvest management of tomato for quality and safety assurance,” *Handbook of Food and Agriculture Organization of the United Nations,* pp. 8-15.

[4] E. Seltzer & J. T. Settelmeyer. (1949). “Spray Drying of Foods,” *Adv. Food Res.*, vol. 2, no. C, pp. 399–520. DOI: 10.1016/S0065-2628(08)60048-8.

[5] F. Maul, S.A. Sargent, C.A. Sims, E.A. & Baldwin. (2000). “Tomato Flavor and Aroma Quality,” *Food Sci. Sens. Nutr. Qual. Food*, vol. 65, no. 7, pp. 1228–1237.

[6] J. A. Adegbola, E. A. Adu, U. D. Anugwom, D. T. Ishola, & A. A. Bodunde. (2012). “Investment opportunities in tomato processing in Kano, Northern Nigeria.,” *Glob. Adv. Res. J. Agric. Sci. (ISSN 2315)*, vol. 1, no. 10, pp. 288–297.

[7] K. Jayathunge, R. Kapilarathne, B. Thilakarathne, K. Palipane, & P.Prasanna. (2012). "Development of a methodology for the production of dehydrated tomato powder and study the acceptability of the product," *J. Agric. Technol.*, vol. 8, no. 2, pp. 765–773.

[8] K. Muzaffar. (2015). "Stickiness Problem Associated with Spray Drying of Sugar and Acid Rich Foods: A Mini-Review," *J. Nutr. Food Sci.*, vol. s12, pp. 11–13. DOI: 10.4172/2155-9600.s12-003.

[9] O. Abdulmalik, I., M. C. Amonye, A. O, & P. O. Umeanuka. (2014). “Appropriate Technology for Tomato Powder Production,” *Int. J. Eng. Invent.*, vol. 3, no. 8, pp. 29–34.

[10] O. O. Arjenaki, P. A. Moghaddam, & A. M. Motlagh. (2013). “Online tomato sorting based on shape, maturity, size, and surface defects using machine vision,” *Turkish J. Agric. For.*, vol. 37, no. 1, pp. 62–68. DOI: 10.3906/tar-1201-10.

[11] S. A. Siddick & S. Ganesh. (2016). “Spray drying technology for producing fruit powders from tomatoes and tamarillo,” *Acta Hortic.*, vol. 1120, pp. 343–348.DOI: 10.17660/ActaHortic.2016.1120.52.

[12] S. Mujumdar. (2020). “Handbook of Industrial Drying,” *Handb. Ind. Dry.* DOI: 10.1201/9780429289774.

[13] S. S. Sobowale, O. P. Olatidoye, L. A. Odunmbaku, & O. H. Raji. (2012). “A Comparative Study on Physicochemical and Rheological Properties of Imported Tomato Paste in Nigeria,” *Sustain. Agric. Res.*, vol. 1, no. 2, p. 51. DOI: 10.5539/sar.v1n2p51.

[14] U. F. Sylvanus & I. E. Victor. (2012). “Impact of tomato processing and wastages in Kano, Nigeria,” “International Journal Of Social Sciences & Interdisciplinary Research,” *Int. J. Soc. Sci.*, vol. 1, no. 3, pp. 297–310.

[15] W. A. Hayes, P. G. Smith, & E. J. Morris. (2010). "Critical Reviews in Food Science and Nutrition The Production and Quality of Tomato Concentrates," *Crit. Rev. Food Sci. Nutr.*, vol. 38, no. 7, pp. 537–564.