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Appropriate Technology for Tomato Powder Production

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Abstract: *In Nigeria, tomatoes are grown in large and commercial scales in the North but consumed equally across the length and breadth of the entire country. Tomatoes are either used fresh or processed into paste, puree, ketchup and powder. Unfortunately, they are not only seasonal but highly perishable and deteriorate few days after harvest, which dampens the farmer's spirit to farming as he is forced to sell off produce at a loss to avert imminent total wastage. Canning of tomato paste has helped to curb this huge wastage, but the capital intensive nature of the industry had resulted into only a small percentage of the produce being absorbed by this industry. Dried tomatoes by direct drying in the sun are more durable but the end product is infested with dirt. This document considers the merits and demerits of spray drying technology for tomato powder production alongside two other alternative technologies of hot air convective dehydration with milling and a novel method called Refractance Window drying.*

Keywords*: Convective, Drying, Powder, Refractance, Spray, Technology, Tomatoes.*

I. Introduction

Food supply is achieved either by increase in production or reduction in loss. Hence eradication of waste is increase in food production. Tomato is the most popular vegetable in today's home gardens and obviously the most commonly consumed vegetable fruit in meals. In Nigeria, tomatoes are grown in large and commercial scales in the North but consumed equally across the length and breadth of the entire country. Tomatoes are either used fresh or processed into paste, puree, ketchup and powder. Unfortunately, they are not only seasonal but highly perishable and deteriorate few days after harvest, losing almost all their required quality attributes and some could likely result to total waste. Although post-harvest loss estimate figure for fruits and vegetables are difficult to substantiate especially in developing countries like Nigeria, it is however estimated that losses as high as about 40-50% of tomatoes and about 20-30% of pepper are lost at post-harvest stage every year (Olayemi et al 2010). The seasonal glut experienced at each harvest apart from marking the extremes of wastage of produce dampens the farmer's spirit to farming as he is forced to sell off produce at a loss to avert imminent total wastage. To curb this huge wastage occasioned by harvest, government through its varied agencies is trying to find a lasting solution to the problem. Canning of tomato paste have helped to curb the wastage, but the capital intensive nature of the industry, the alteration in the taste of the product canned (as additives are added to aid in preservation) and the bulky nature of the paste product as well as poor durability have all contributed to limiting the establishment of canning industries. As a result only a small percentage of the produce is absorbed by this industry.

Dried tomatoes though more durable and without any need for additives are currently produced by direct drying in the sun and in the open. The end product is infested with dirt and sand making it unhygienic to consume. Government while dissuading this practice is making concerted efforts through its agencies towards evolving an economical technology for the production of dried tomato flakes and powder.

Tomato is a major vegetable crop that has achieved tremendous popularity over the last century. It is grown in practically every country of the world in outdoor fields, greenhouses and net houses. World production and consumption has grown quite rapidly over the past 25years. World tomato production in 2001 was about 105million tons of fresh fruit from an estimated 3.9million hectares (Ayandiji et al 2011).

Tomato fruit is made of water and organic compounds (solids) of which 10% is skin and seeds. It has been shown that sugar content is positively correlated with total soluble solids content in tomato fruit. Hence generally, soluble solids content measurement may give a fair estimate of the sugar level in tomato fruit. The sugars are mostly glucose and fructose and constitute about 65% of total soluble solid in expressed fruit juice. Whereas the acids are mostly malic and citric acids, organic acids comprise about 15% of the dry content of fresh tomato (Turhan and Seniz 2009).

Fresh fruit and vegetables are very important sources of vitamins that are essential for healthy human diet. Vitamins account for a small portion of the total dry matter. Minerals commonly found in tomato fruit are

K, Ca, Mg and P and may reach 8% of the dry matter. The varied properties of the varied constituents of tomato inform the complex nature of the drying mechanism to be envisaged in the drying of tomatoes. Different elements with different transition temperatures and heat capacities within the same compound points to assured drying difficulties as one reason that makes spray drying of tomato pulp a bad option. Studies and experimentations were executed to bring to the fore the most suitable method for drying tomatoes.

II. Methodology

Samples of different varieties of tomatoes were chemically and microbiologically analyzed. Their proximate compositions and characteristics were determined. Further laboratory drying experimentations were conducted in a cabinet dryer, and spray dryer. Also samples were dried using the novel Refractance method. The analysis and cabinet drying experimentations were done at the College of Science and Technology laboratory of Kaduna Polytechnic, Kaduna, Nigeria. The spray drying test was performed at the Department of Food Technology of the Federal Polytechnic, Bauchi, Nigeria while the Refractance window test was done at the Hydraulic Equipment Development Institute, Kano, Nigeria.

III. Literature of Drying Equipment

3.1 Spray Drier

This type of drier is used extensible in the food industry for drying solution and slurries. The food material is introduced into the drying chamber in the form of a fine spray where it is brought into intimate contact with a stream of heated air. Thus very rapid drying occurs and a dry powder is produced **(**Brennan et al 1981).

The external components of a spray drier include:

a. An air heating and circulating system
b. A spray form of device
c. A drying chamber and
d. A product collector.

A schematic diagram of a spray drier is shown in Fig. 1 below.

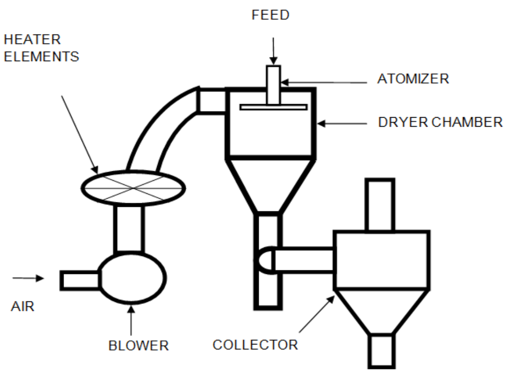

Figure 1: Schematic Diagram of a Spray Dryer

Though the equipment has been used to successfully dry a number of products, spray drying is one of the most complex methods for fruit juice drying. Naturally hygroscopic and thermoplastic property of fruit juice is the basic problem in transport and handling of fruit juice powder produced in spray dryer. For fruit juice powder production two complex problems were available, stickiness of powder and its handling and the other was related to fruit juice natural characteristic that caused no powder production (Chegini and Ghobadian 2007). Tomato pulp is a typical example of a product that is very difficult to spray dry due to the low glass transition temperature of the low molecular weight sugars present (Goula et al 2001).

The sugars found in tomato products are mainly dextrose and levulose, with a Tg of 31 and 5 degrees centigrade respectively. Generally stickiness is a phenomenon that reflects the tendency of some materials to agglomerate and/or to adhere to contact solid surface and can be described in terms of cohesion (particle to particle stickiness) and adhesion (particle to solid wall surface stickiness (Goula et al 2001). In recent years, the stickiness problem of sugar products such as fruit juices has been related to their low glass transition temperature (Tg). Maintaining wall temperature lower than the Tg of the powder could reduce deposition of such powders. To successfully dry these sugar-rich products, either the design of the dryer has to be modified or some additives (e.g. maltodextrim) are to be added before drying to increase the Tg of the product. Sometimes, rotating air broom systems are attached to the spray dryer to maintain low wall temperature (Mani et al 2002).

Glass transition is a method to characterize a thermal based property of a polymeric material. The glass transition temperature is the temperature which defines the change of the polymer from a hard glass-like state to rubber-like state. The different transition temperatures of 31 and 5 degrees centigrade for two member polymers of tomatoes underlines the reason for the stickiness and general inconsistencies in the one chamber one temperature production of tomatoes witnessed in spray dryer.

Apart from difficulties of powder production experienced in a spray drier, the energy consumption demand of the equipment renders it inappropriate for a process intended as a cost–saving measure to save excess produce and add value. In 2000, the U.K government’s Energy Efficiency Best Practice Programme commissioned a survey to determine the energy consumption of spray dryers within the chemicals, foods and ceramic industries. The results of this survey which include dryers having evaporation rates ranging 0.1 to 12t/hr revealed values of the specific energy consumption Es varying from 3 to 20GJ/t water evaporated. The average for all dryers included in the survey was 4.87GJ/t. It was also estimated that 29% of the energy supplied to the dryers included in the survey was being wasted (Baker and Mckenzie 2005). Raghavan 2003 in a study of the energy consumption of the artificial drying operation of dryers which are based on hot air convective principle where air is heated by the combustion of fossil fuels prior to being forced thorough the product, estimates energy consumption of 0.38 to 0.63 GJ/t of grain (Raghavan et al 2004). Comparison shows the average spray dryer consumes more than thirteen times the energy utilized by a convectional dryer using fossil fuel.

3.2: Tunnel Dryer

This type of equipment provides a means of drying fruits and vegetables in piece form on a semi-continues basis at high throughputs. It consists of a tunnel which may be up to 24m long with a square or rectangular cross-section of the order of 2m by 2m.The wet food materials is spread in even layers on trays of slatted wood or metal mesh. The trays are assembled in stacks on trucks, clear spaces being provided between the trays to permit passage of the drying air. The loaded trucks are fed one by one, at suitable intervals into the tunnel. As one truck enters the wet end of the tunnel, a truck of dry product is removed from the other dry end. Air is moved by fans through heaters and horizontally between the trays although some through-flow does occur. Air velocities of the order of 2.5 - 6m/s are normally employed (Brennam et al 1981). Fig. 2 is a schematic diagram of a tunnel dryer.

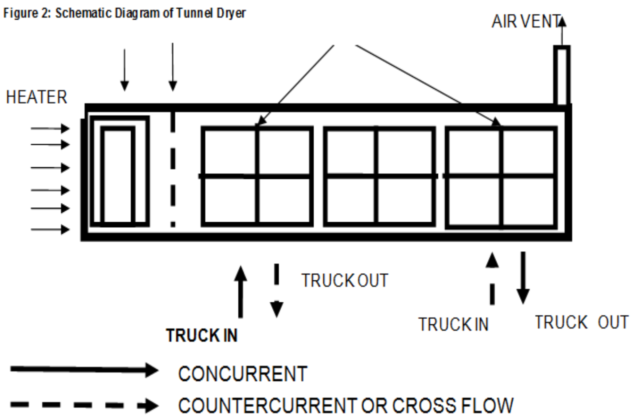

Figure 2: Schematic Diagram of Tunnel Dryer

Tunnel dryers are usually classified in terms of the relative direction of movement of the material and the air. Full arrows in the tunnel dryer diagram are used to depict concurrent dryer operation, while dashed arrows indicate counter current system. For the concurrent system, the characteristic features are:

a. High rates of evaporation are achieved at the wet-end of the tunnel as relatively high air temperature can be used without the dangers of overheating the material. This high initial drying rate results in a product of low bulk density as little shrinking accrues.
b. As the product moves down the tunnel it comes into contact with cooler moist air. The drying rate falls off and heat damage to the product is minimized.
c. Very low moisture contents are difficult to achieve due to poor drying conditions at the dry end of the tunnel. The characteristic of the countercurrent or cross-flow system are:
a. Relatively low initial rates of drying occur at the wet end of the tunnel because of the relatively poor drying characteristic of the air. This causes severe shrinkage of cellular material giving a product of high bulk density.

b. The conditions at the dry end of the tunnel of hot dry air are such that low moisture contents are attainable but the risks of overheating the product are high.
c. This system is usually more economical in the use of heat than the concurrent system.

A collaboration of the Faculty of Agriculture, Rajarata University of Sri Lanka, Department of Food Science and Technology, Sabarawagamuwa University of Sri Lanka and the Institute of Post Harvest Technology, Research and Development Centers, Anuradhapura Sri Lanka towards the development of a methodology for production of dehydrated tomato powder recommends the employment of a countercurrent tunnel dryer. The research establishes hot water blanching of ripe tomatoes at 60degrees centigrade for one minute as the most effective pre – treatment in preservation of red colour of the dehydrated product. Among different drying temperatures tried out in this study, drying at 55degrees centigrade was found to be the best that produced the acceptable colour of tomato slices with lower drying time of 48 hours. The dried slices were ground using a laboratory grinder to get tomato powder (Jayathunge et al 2012). This is a very recent study and experimentation executed and inferred in 2012 and correlates 2007 recommendations of the Technical Center for Agricultural and Rural Co-operation (CTA) in Wageningen, The Netherlands on preservation of tomatoes through tomato powder production. The five steps for production of tomato powder enunciated in the said recommendations are:

a. Choosing Tomatoes: Select tomatoes that are ripe, free of disease and mould
b. Washing: Wash the freshly harvested tomatoes in clean water in a large bucket
c. Slicing: Cut the slices 0.5cm thick
d. Drying: For small scale preparation use solar drying but cover with mosquito netting to prevent contamination. For commercial scale production, dry tomato slices using a hot air dryers.
e. Milling: Mill the dried tomato slices using a hammer mill fitted with a sieve of appropriate mesh size (CTA Practical Guide Series No. 12).

3.3: Refractance Window (Rw)

A new model development technology, Refractance Window offers both relatively low cost operation with excellent retention of colour, flavour and nutrients. This technology can be applied to both evaporation for concentrations and complete drying to a powder. The secret of this technology is its ability to create a window for the passage of infrared energy used for drying and to operate at relatively low temperature. Hot water provides the heating medium utilizing heat transfer via radiation. Another unique attribute is its ability to self-regulate as the material dries which means that heat damage is kept to a minimum (Clarke 2004). It is noted that when water is placed over a heating source, infrared energy is transferred throughout the water by convection. The heat energy then radiates from the water, primarily through evaporation. When the water is covered by a transparent membrane such as plastic and placed over a heating source, evaporation and its associated heat loss are blocked or refracted and heat loss can only occur by conduction from the sides of the container.

It is discovered that when moist raw material is placed on the plastics membrane's surface, the water in the material creates a window that allows for the passage of infrared energy through the material. Heat behaves as if there were no membrane present and is directly transferred to the water remaining in the material. When the water in the material on the plastic membrane's surface evaporates, the window of infrared energy closes automatically and refracts back into the heated water source, cutting off heat energy form the material.

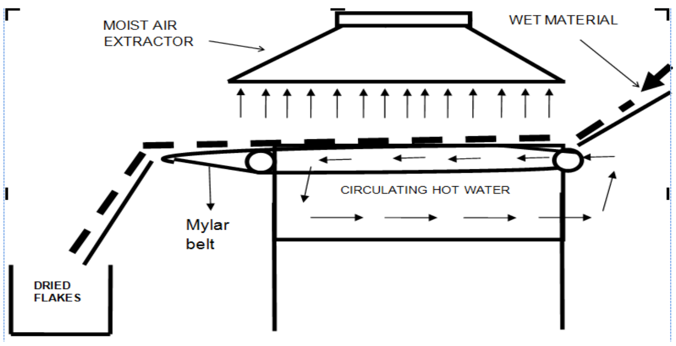

Figure 3: Schematic Diagram of Refractance Window Drying System

A belt conveyer arrangement floating on the surface of a tank containing circulating hot water is the Refraction Window technology for continuous drying of moist materials. The belt is a food grade Mylar transparent polyester film. A schematic diagram of a Refractance Window dryer is shown in Fig. 3 above. Effect of Refractance Window drying method on quality of produced tomato powder as compared to the tunnel drying method was studied by a collaboration of the Department of Food Science and Technology and Department of Agriculture Engineering, at the Al-Azhar University, Cairo Egypt in 2011, with the key results given hereunder. Tomatoes were chopped into pieces with knife and ground into rough pulp using a blender. Subsequently, the pulp was passed through a finisher to remove the skins and seeds. The pulp was dried in a convection drying at 60 ± 2^0C and a Refractance window at three different temperature/time (a) 90 ± 2^0C/40minutes (b) 75 ± 2^0C/60minutes and (c) 60 ± 2^0C/75minutes, till moisture content reached to 11-13%. After drying, the dried film of tomato pulp was collected from the trays or glass. The dried flakes were ground by using a laboratory disc mill to pass through 20 mesh sieve. The produced powder was desiccated at 18 ± 2^0C in sealed plastics bags until analysis (Abdul-Fadl and Ghanem 2011**)**. For the sample sizes used, the elapsed drying time to reach the adequate moisture content of (11. 3%) in the final product of tomato powder by using convective drying method requires 16hours. On the other hand, using the Refractance window drying method to get the adequate moisture content within the limits of 10.95 – 13.69 % were ranged between 40 and 75 minutes. With regard to the production cost of one kilogram of tomato powder, the cost of production using the RW drying system was three times lower than the cost of production by convection drying system. Also the quality characteristics of tomato powder production by RW drying method was significantly improved when compared to the product produced by convection drying method (Abdul-Fadl and Ghanem 2011**)**.

IV. Results

The following is the chemical and microbiological analysis report.

A. Chemical Analysis

COMPONENT	POWDERED TOMATO (%)	FRESH TOMATO (%)
Moisture	6.2	93.1
Protein	1.9	0.6
Fat	0.3	0.1
Carbohydrate	76.6	3.9
Fibre	8.4	1.0
Ash	6.1	1.3
Ph	3.8	
TSS	4-7.8	

B. Microbiological Analysis

Mesophilic Bacterial Count (Cfu/g) - 1.30 x 10-1
Yeast Mold Count (MPN) - <30
Coilform Count (MPN) - Nil.

C. Experimentations

were performed at the range of drying temperatures of 50-60^0C for tray drying and a range 120-180^0C and mean temperature of 140 ± 50^0C for spray drying. The cabinet dryer dried the product in two days and quarter. This correlates the literature on tunnel dryers. Spray drying was however not successful as the material clung to the walls of the dryer chamber. Twice we dismantled the chamber and scraped the stuck tomatoes before giving up after the third trial. This confirms the stickiness encountered in drying tomatoes by spray drying. Refractance window method proved to be the best as products dried in about one hour thirty minutes.

V. Conclusion

Tests show that tunnel drying is effective but the long hours and energy consumption are the disadvantages. Hence tunnel drying with milling has been the hitherto successful conventional method used to produce tomato powder. Spray Drying is infested with difficulties and complexities and cannot be recommended for obvious reasons which include the stickiness of materials on the dryer chamber and the huge energy demand of the system. The emergence of Refractance Window method offers obvious advantages. It is a novel technology and currently the state of the art in the drying of fruits and vegetables. However much work is needed before a full scale commercial plant can be successfully actualized.

Figure 4: Spray Dryer Developed at the Hydraulic Equipment Development Institute (HEDI), Kano, Nigeria

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