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Analysis of cocoa processing systems and classifications of cocoa dryers

Abstract: The processing of cocoa involves a couple of technological processes such as roasting and drying which consume lots of energy. The ever increasing cost of energy has created the need for continuous optimization of the technological processes to minimize their operational cost. The selection of the appropriate equipment for each process is the first step to optimize the entire process. In recent times, drying technologies have evolved and have become more diverse and complex. Also, there is the need to meet stricter quality specifications, higher production rates, higher energy costs and stringent environmental regulations. As a result, selecting the right dryer for the right product has become an increasingly difficult task. In this paper, we attempted to describe the technological stages of cocoa processing and classified the various types of dryers available for the various stages of cocoa processing. This is important because the engineers responsible for the selection of a drying system need to be informed on the available equipment on the market, what the key criteria are in the selection process and thus arrive at alternative possibilities before a choice is made.

Keywords: Cocoa; drying; roasting; dryers; classification; value chain; processing.

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Introduction

Cocoa beans just like any other cash crop goes through numerous postharvest procedures, which are aimed at preventing and minimizing possible losses as well as enhancing certain physical and chemical qualities. These processes comprise the breaking of the pod to remove the beans, fermentation, drying, selection and storage. Fermentation and drying are the initial but most important processes which are undertaken by the individual cocoa farmers.[7][8] While fermentation is essential in the creation of the complex organic components essential to the taste of final product (chocolate etc), drying helps to prolong shelf life since the higher the moisture content, the higher the chances of mold development.[11]

As the basic raw material for chocolate and many other chocolate based products, cocoa beans go through different technological processes upon arriving at the factory from the cocoa farm, before they end up with the final consumer. Technological processes such as roasting and drying are very energy intensive and considering the ever increasing cost of energy, there is the need for continuous optimization to reduce their operational cost. Choosing the right equipment for the right process does not only enhance the energy efficiency for the entire process, but also goes a long way to enhance the quality of the final product which is paramount for the survival of every business.

Due to the fact that drying technologies have evolved and become more diverse and complex and also exasperated by the need to meet stricter quality specifications, higher production rates, higher energy costs and stringent environmental regulations, selecting the right dryer for the right product has become an increasingly difficult task.[9] It is therefore necessary for an engineer responsible for the selection of a drying system to be aware of what is available in the market, what the key criteria are in the selection process and thus arrive at alternative possibilities before a choice is made. This paper aims at describing the technological stages of cocoa processing and presenting the various types of dryers available for the various stages of cocoa processing.

The value chain of cocoa beans

A value chain is a sequence of interconnected business activities that ultimately add value to products or services as they move through production, processing, marketing and sales.[3] During this process, inputs, raw material, services, intermediate and final products are owned by different actors or stakeholders, with each actor in the chain adding value to the product.

The cocoa value chain in Ghana continues to experience phenomenal growth over the past few years. As the most important crop exported from Ghana, cocoa contributed up to 4.5% of the country's GDP and made up 30% of total export earnings in 2011. Various initiatives by the government helped to increase the total production of the beans from 450,000 tonnes in 2000 to over a million tonnes in 2011.[2] About 90% of cocoa is grown by smallholder farms.[1] Cocoa dominates the agricultural sector in the country and is a major source of income for approximately 800,000 farmers and many others engaged in trade, transportation, and processing of cocoa.[5] This explains the continuous emphasis on research and development in the cultivation, storage and processing of cocoa in Ghana.

In the case of cocoa in Ghana, the stakeholders will be in the form of local actors, which will be made up of the farmers, government agencies such as Ghana Cocoa Board (COCOBOD), Cocoa Marketing Company, Licensed Cocoa buying Companies (LBC), haulers, warehousing and logistic service providers, domestic chocolate manufacturers, domestic grinders, distributors, retailers and local consumers. There are also international actors which are made up of multinational brokers/traders, shipping lines, international warehouses, international grinders and manufacturers, and international consumers. The value chain of the Ghanaian cocoa is illustrated in figure 1.

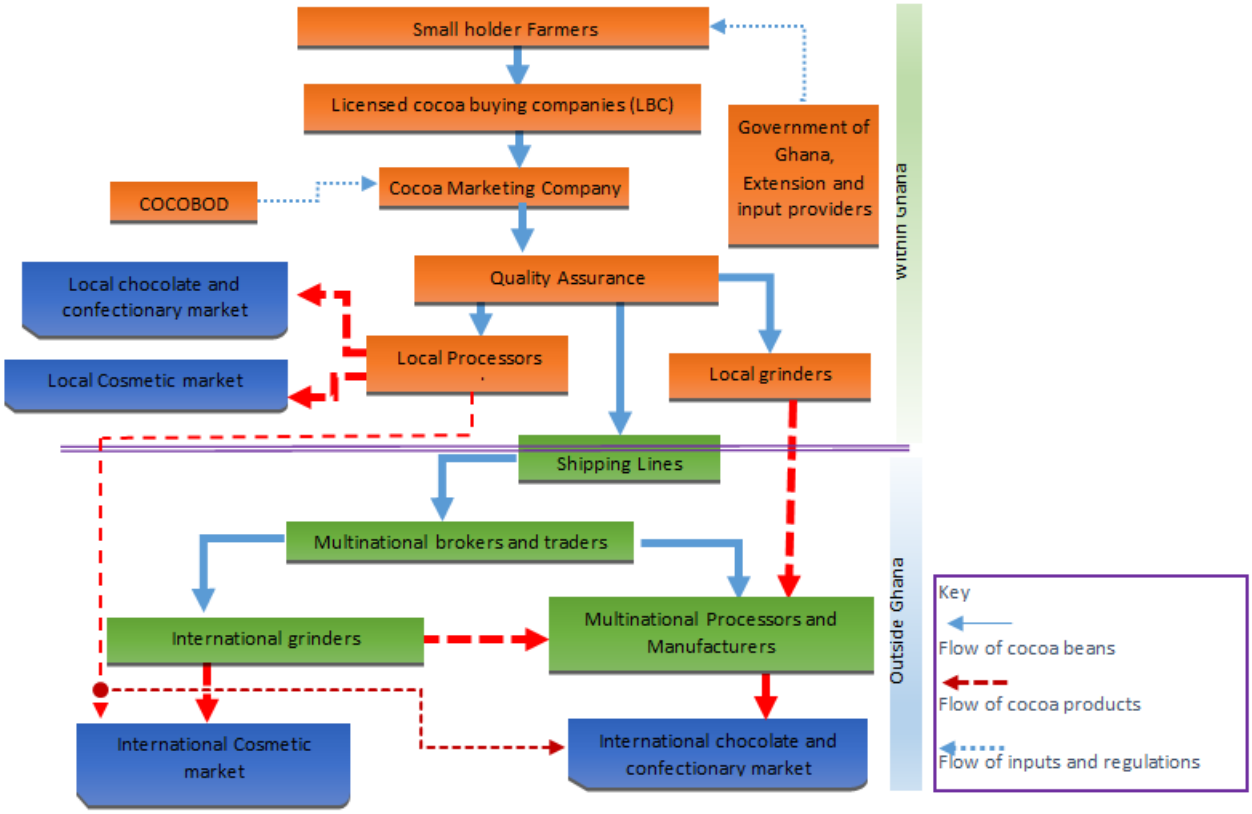

Figure 1. *Value chain diagram of Ghanaian cocoa*

As shown on figure 1, the value chain of Ghanaian cocoa starts from the growing, harvesting, fermenting and drying of cocoa beans by small holder farmers before the dried beans (at 7.5-10% moisture content) are sold by small holder farmers to the various registered or licensed cocoa buying companies (LBC), who operate under the supervision of COCOBOD. They are sometimes further dried by the LBC to the required moisture content of 6.5-8.5% and resold to the COCOBOD (a government agency), through its marking wing: Cocoa Marketing Company (CMC), which is the sole exporter of cocoa beans in Ghana.[4] COCOBOD then resells the beans to domestic industries for local processing or export to cocoa manufacturing and processing companies abroad. According to data available at [4], the main export destinations of Ghanaian cocoa during the 2012-2013 cocoa season were, the European Union, Japan, Malaysia and the United States.

Cocoa Processing Technology

The quality of a cocoa product in any form is determined from the time the cocoa pod is plugged from the cocoa tree on a cocoa farm. These pods are split open and the beans are extracted, fermented and dried, before the dry beans arrive at a cocoa processing plant.

At the plant, the beans are cleaned and sorted according to the beans sizes to avoid smaller beans burning during roasting. The beans are then roasted to fully develop the cocoa flavour and to complete the drying process, which were started during fermentation and drying. The roasted beans are then broken or cracked to loosen the shells from the nibs and these fractions are then winnowed to separate the broken shell from the nib by a stream of air. The breaking and winnowing steps separate the essential ingredient of the cocoa beans, the kernel, most often described as the nib, from its shell. The nibs are then grinded into cocoa liquor, a paste of cocoa solids suspended in

cocoa butter. Cocoa liquor as a semi-finished product, is supplied to the chocolate industry and forms the basis for the production of cocoa powder and cocoa butter, as shown on figure 2.

Alkalizing is an optional treatment of cocoa liquor or beans. It involves treating the cocoa liquor or beans with an alkali solution such as potassium or sodium carbonate, primarily to modify the color and flavor. This process may happen before, during or after roasting.

Afterwards, the liquor is pressed to separate the oil (cocoa butter) from the solid mass (cocoa press cake). The amount of butter extracted from the liquor is controlled by the manufacturer to produce press cake with different proportions of fat. The press cake and cocoa butter are processed in two different directions and merging later in the processing line depending on what products are being made. The cocoa butter is used in the manufacture of chocolate or sold to the cosmetics market. The cocoa press cake is broken into small pieces to form kibbled press cake, which is then pulverized to form cocoa powder.

In chocolate manufacturing, sugar, cocoa butter, milk, emulsifying agents and cocoa butter equivalents are added to the cocoa mass and mixed to form a thick cocoa mixture. The proportions of the different ingredients depend on the type of chocolate being made. The resulting mixture then undergoes a refining process by travelling through a series of rollers until a smooth paste is formed. Refining improves the texture of the chocolate. It will later go through conching, which is a treatment whereby chocolate is kept in continuous movement to allow the cocoa mass to thicken and to develop into a homogenous substance as well as to further develops flavor (as it allows volatile acids to escape).

Finally, to prevents discoloration (fat bloom), the mixture is then tempered or passed through a heating, cooling and reheating process. Tempering is important for the right crystallization of the cocoa butter. After tempering, the mixture is then put into moulds and allowed to harden. During the hardening process the volume of the chocolate is reduced, allowing the chocolate to come out of the mould automatically. The chocolate product can then be packaged for distribution.

With instant cocoa powder manufacturing on the other hand, sugar, nonfat milk (cream milk limits the shelf life of the powder) and emulsifying agents are added to the cocoa powder and mixed to form a thick cocoa mixture. This mixture is then instantized. The principle of instantizing is to cement the sugar, milk and cocoa particles together by subjecting them to an atmosphere of wet steam, which wets the sugar just sufficiently to form a film of syrup on the particle and this brings about adhesion to, and partial wetting of the cocoa particle.[13] The proportions of the different ingredients depend on the type of powder being made. The resulting mixture then undergoes a refining process before it is dried to produce the powder. Depending on the type of drying used, the last stage of the process will require milling a dry cake into powder. The instant cocoa powder can then be packaged for distribution.

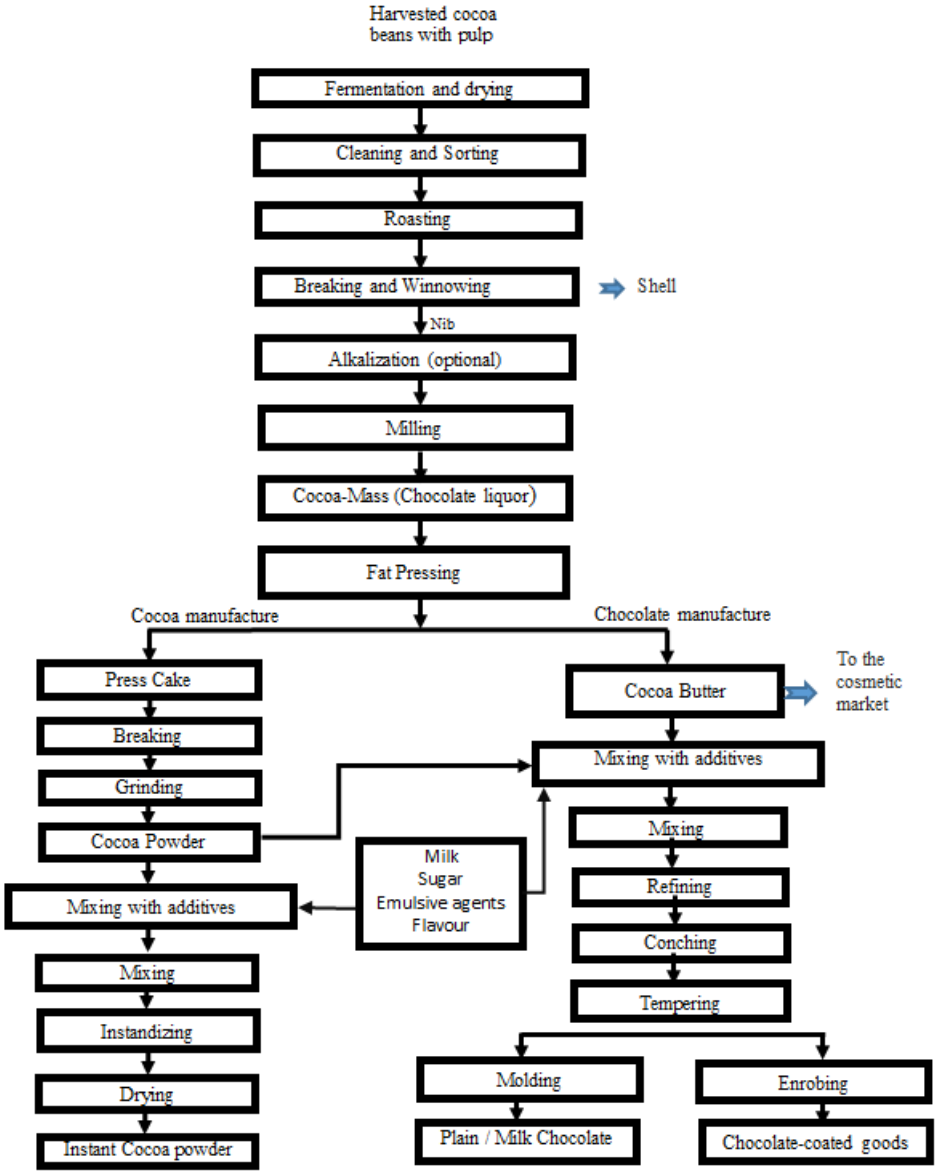

Figure 2. *The technologies of cocoa processing*

Thermal Processes and drying method classifications

From the processes describe above, it is clear that cocoa processing generally involves a series of energy intensive sub processes. As a result, optimization of these processes will require the optimization of some or all these sub processes. The thermal sub processes in the process are the most energy intensive of the entire process and as such, optimizing them will lead to a more energy efficient process.

Thermal processing is a significant part of cocoa processing, where cocoa beans, paste or mixture are exposed to an elevated temperature for a period of time to make them suitable for consumption or incorporation into further processing. The main aim of thermal treatment is to extend shelf life by reducing bacterial counts to acceptable levels, and to produce a desirable cocoa aroma and flavor in the product.

Among the most prominent thermal sub processes in cocoa processing will be the various stages of drying that are embedded in the process. This include drying of the beans by the small holder farmers, roasting of the beans and drying the instant cocoa powder. The sequence of the

thermal sub process is illustrated on figure 3. In optimizing these sub processes, choosing the right drying method and dryer type will play a significant role.

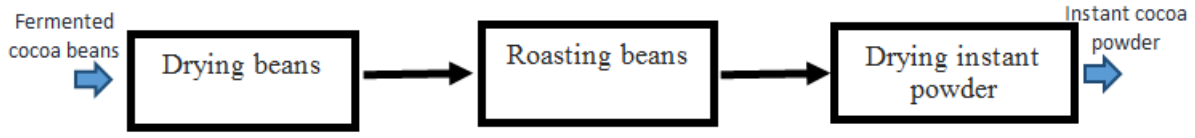

Figure 3. *Drying sequence in cocoa processing*

Drying cocoa beans and instant powder

Drying is a separation operation, which converts a solid, semi-solid or liquid feedstock into a solid product by evaporation of the liquid into a vapor phase via application of heat.[9] In the case of cocoa, beans must be dried from an initial moisture content of 60% down to 7.5% in order to prevent mould growth during storage. Drying occurs by effecting vaporization of the liquid by supplying heat to the wet beans or mixture. During beans drying various biochemical changes that have commenced during fermentation continue during drying provided sufficient moisture is still present but eventually ceases at the end of drying. [11]

During drying, heat may be supplied to the beans/mixture by convection (direct dryers), by conduction (contact or indirect dryers), radiation or volumetrically by placing the wet material in a microwave or radio frequency electromagnetic field. Heat applied to cocoa during drying should usually be below 60^{o}C, since above such temperatures cocoa beans loose certain volatile nutrients such as fatty acids and will also cause beans to puff [11]. Also, such temperatures allow the beans to dry more slowly to allow the flavour the development processes that started during fermentation to complete.

Over 85% of industrial dryers are of the convective type with hot air or direct combustion gases as the drying medium.[9] The heat is applied to move the liquid in the bean/mixture to the boundary before it is transported away by the drying gas.

Cocoa drying techniques vary among the farmers and manufacturers and it ranges from natural sun drying techniques to artificial hot air techniques. The selection of a drying technique largely depends on the production scale and affordability in terms of cost.

Roasting of cocoa beans

Roasting is required to develop a complete chocolate flavor that was started during the fermentation and drying processes and to further reduce the moisture content to about 2%.[2] Roasting temperatures range from 90-170^{o}C depending on the process, equipment, type of nib being processed, and the end product required.[2][7] Roasting also drives the loss of more volatile acids and other substances that contribute to acidity and bitterness in cocoa beans. Exposure of beans to such temperature during roasting is also essential for the elimination of bacteria that the beans were exposed to during fermenting, drying and transportation in the open air. Roasting causes the bean to puff out and as a result, facilitates easier separation of the nip from the shell. Different cocoa processing companies employ different roasting methods depending on which variety of cocoa is being processed or what the final product should be. The most widely used method of roasting cocoa beans is of the convection type. Since the principles of operations of a roaster is similar to an industrial dryer, we will refer to them as dryers, for uniformity.

Classifying Dryers

Generally, the choice of a suitable dryer will depend on the type of product (solid, liquid, paste etc) that needs to be dried, its thermal properties as well as its storage and stability requirements. This is because a product's storage and stability requirements largely determine the final moisture, and the final moisture content determines the drying time and conditions required for drying.[10]

Currently, some of the numerous criteria used to classify dryers include, the mode of heat transfer to the product in the dryer (convection, conduction, radiation etc.), the mode of operation of the dryer (batch or continues), the drying medium (air, steam etc.), drying temperature (below boiling temperature, above boiling temperature, below freezing point, etc.), relative motion between drying medium and drying solids (co-current, counter-current, mixed flow, etc.), number of stages (single, multi-stage), etc. [10] Detail descriptions of dryers and drying technologies can be found in [9][10][12].

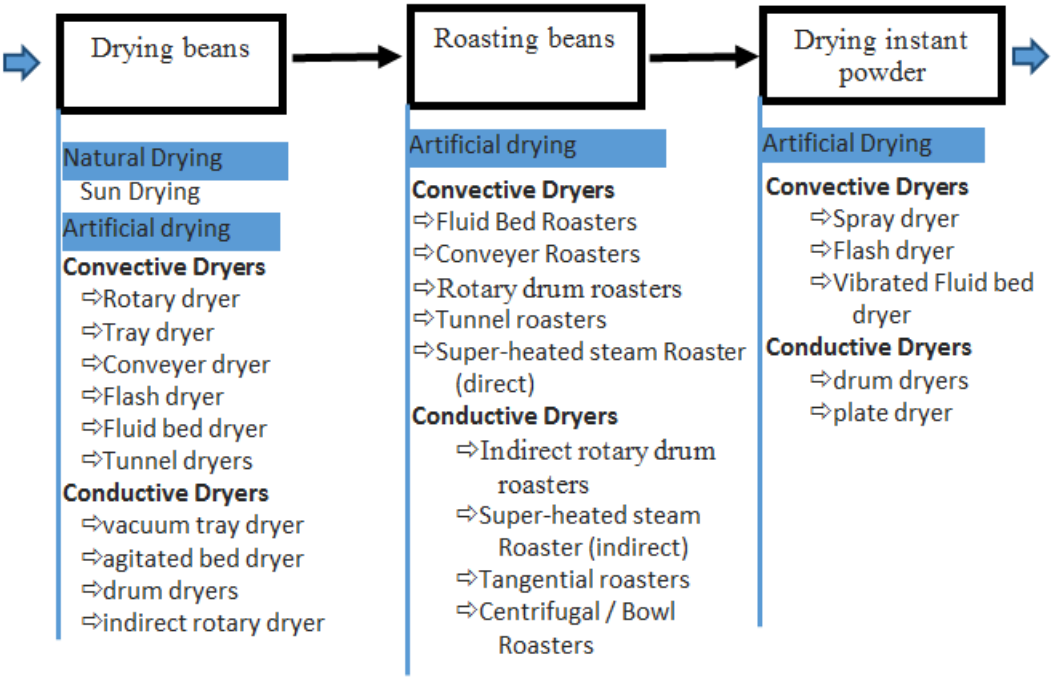

Figure 4. *Classification of dryers in cocoa processing on heat transfer method*

Since in the course of cocoa processing, cocoa in different forms (bean, paste or mixture) with different properties, need to be thermally processed to different final moisture contents, a suitable dryer needs to be selected for each process. The selected dryer should be capable of taking cocoa in a particular form (bean, paste or mixture) as an input and dry it to the required final moisture content. In some cases as shown in figure 4, the output product from one drying process can be preprocess to become the input product for another dryer. Since currently no one dryer exists that can handle all the three drying stages effectively, different dryers will have to be selected for the different drying stages. Figure 4, illustrates the classification of dryers in cocoa processing based on the mode of heat transfer from the drying system to the product (beans, powder). Figure 5 on the other hand, illustrates the classification of dryers in cocoa processing based on both the method of operation and the mode of heat transfer.

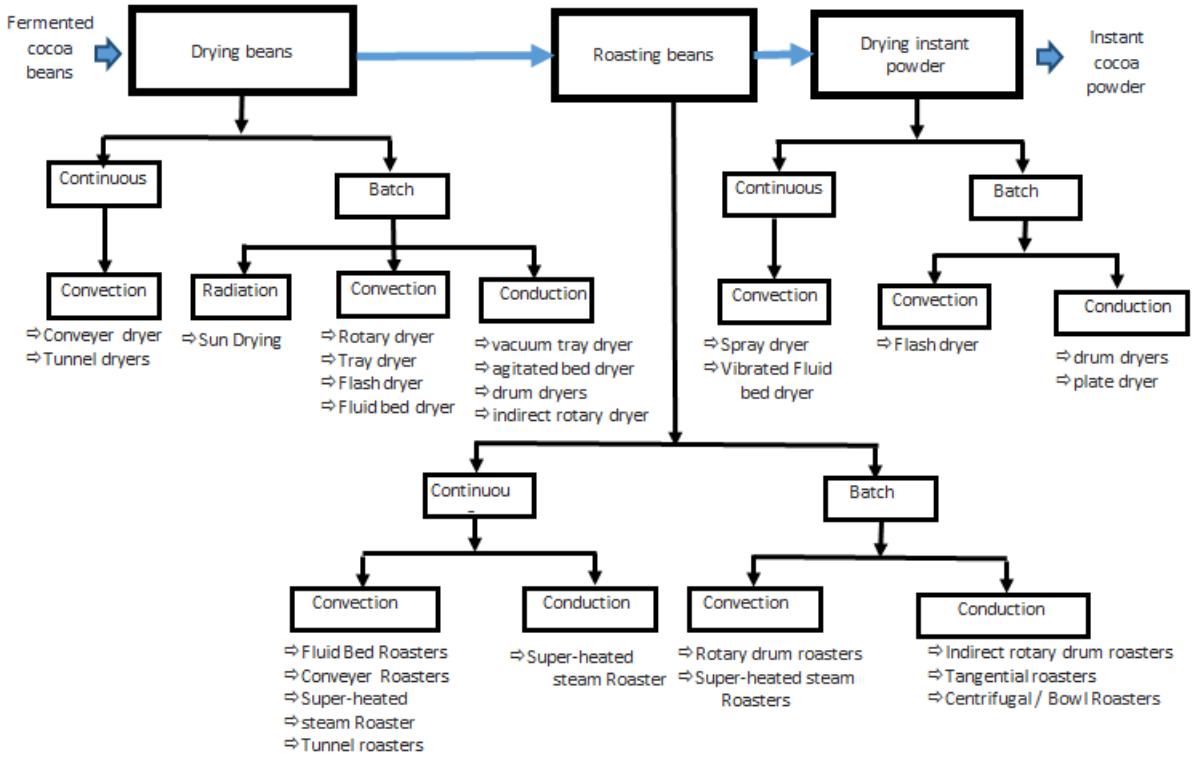

Figure 5. *Classification of dryers in cocoa processing based on mode of operation*

Conclusion

The journey of a cocoa bean from a cocoa tree on a cocoa farm in Ghana, to the shelves of shops in Europe is a very long and complex one. Even though the beans change hands throughout this journey, there is the need for proper handling to achieve the best of quality in the final products. Apart from the physical handling, cocoa beans also go through various chemical and technological processes to achieve the desired quality.

Usually when cocoa beans arrive to the factory they are either processed into chocolate, instant cocoa powder or other cocoa confectionaries and cosmetic products. Chocolate and cocoa powder manufacturing is an energy intensive process and therefore need constant optimization to cope with an environment of increasing cost of energy and high quality demands from consumers.

In this work, the technological process of chocolate and instant cocoa powder manufacturing was analyzed and the most energy intensive sub processes are identified to be the thermal sub processes. Since the first step to optimizing these processes will be the selection of the most appropriate equipment for the right processes, the classification of dryers available is very essential. Classification of the various types of dryer available for the various stages of cocoa processing based on the systems mode of operation and the heat transfer method were presented. This is important because the engineers responsible for selection of a drying system need to be aware of what is available in the market, what the key criteria are in the selection process and thus arrive at alternative possibilities before a choice is made.

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Анализ технологического процесса переработки какао и классификация какао-сушилок

Аннотация: Переработка какао включает в себя ряд технологических процессов, таких как обжарка и сушка, которые связаны с большим потреблением энергии. Постоянно увеличивающаяся стоимость энергии создает необходимость оптимизации данных технологических процессов с целью минимизации стоимости их эксплуатации. Выбор надлежащего оборудования для каждого процесса становится первым шагом для оптимизации всего процесса. В последнее время сушильные технологии продвинулись вперед и стали более разнообразными и сложными. Кроме того, существует необходимость удовлетворения строгих требований к качеству, более высоких темпов производства и строгих экологических норм. В результате выбор подходящего сушильного оборудования для конкретного продукта становится все более сложной задачей. В этой статье представлены все стадии технологии переработки какао, а также создана классификация существующих сушилок на различных этапах переработки. Это важный момент, поскольку технические специалисты, ответственные за выбор системы сушки, должны быть информированы об имеющемся на рынке оборудовании, и о том, какие ключевые критерии используются в процессе его выбора и, таким образом, иметь возможность рассмотреть альтернативные варианты прежде, чем сделать выбор.

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Ключевые слова: Какао; сушка; обжарка; сушилки; классификация; цепочка добавленной стоимости; переработка.

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