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Study of Process Variables Associated with Manufacturing and the Role of Automation in Packaging of Biscuits - A Review

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Abstract

Biscuits are one of the most popular and widely consumed edible commodities across all ages of people. Their preparation and processing from raw dough is not simple. It requires a lot of human effort and production cost. In order to reduce human labour and flaws resulting due to human work as well as to conserve time and manufacturing cost, most of the processing industries are trying their hand in automation. Automation, as we all know, is the process of utilizing self-propelled and multifunctional equipment's capable of accomplishing specific tasks, which are given to them themselves with no or negligible human assistance. Even though, they are having their own demerits like escalated capital and maintenance cost, sophisticated working environment and expert labour, their merits are far more abundant. This paper deals with an elaborate study about the effect of various process parameters implemented in the manufacturing and packaging of biscuits as well as the necessity and importance of automation implemented in the manufacturing and packaging of biscuits based on reviewing various research articles. It is observed that the functioning of process parameters are studied under three phases. First, Evaluation of flame geometry and air fuel mixture ratio of diesel fired burners. Second, Process parameters involved in effective baking of biscuits and third Automation in packing biscuits in cartons. From the detailed study, it is observed that the diesel firing can be normally analysed through any of the common analysis and evaluation software using parameters such as flame geometry, types of oven used, heat properties of flue gas recirculation, etc. It is identified that the parameters like dough composition, dough weight, baking temperature, baking time, moisture content, etc. exert a lot of influence over the effective baking of biscuits. Finally, it is observed that the effectiveness of packaging of biscuits in cartons depended on the area of the carton and area of each box containing biscuits to be filled in the carton. The packing of biscuits in the cartons is still done manually, which is a matter of concern.

Keywords: Automation; Baking; Biscuits; Flame geometry; Packaging; Temperature

1. Introduction

Generally, biscuits or cookies, as they are fondly called, fall under the category of Fast Moving Consumer Goods (FMCG). As the name of the category suggests, the volume of production, transportation and consumption rate of these goods will be enormously high. While considering the biscuits, there are many stages involved in the production starting from the preparation of the raw materials followed by processing them and finally packing the biscuits. Here we consider three vital stages in the effective production of the biscuits by optimizing the process parameters influencing them. First is the procurement and transportation of raw material from various sources to the manufacturing unit. Second will be the preparation of the dough by mixing water with the available raw material. Once the dough is prepared in the basin, it alters its shape to the shape of the container. Third and final step is to transport the dough through the conveyer. The shaped dough, passing through the conveyors reaches the baking furnace. Here the shaped dough gets baked in a baking oven which lies beneath the furnace. In the furnace, diesel is used as fuel and it is sprayed in order to produce combustion which in turn dissipate heat and the heat is transferred evenly into the baking oven to bake the biscuits. By means of convective heat transfer, the heat from the heat source gets transferred to the dough and bake it by radiating it. Generally baking is a process of preparing food using dry heat. The baking of biscuits depends on various parameters such as the composition and properties of raw materials used, baking temperature, source of heat, moisture content in the dough and the weight of the dough taken. So, apt parameters are required to achieve proper and effective baking. Once the baking is done, the baked biscuits are moved out of the conveyor and they get inspected for their quality. After inspection, the biscuits move to the packaging section. Here by means of automation, the biscuits get packed based on the quantity to be packed. Finally, they are arranged inside boxes to be further transported to the required locations either wholesale or retail. The processing of biscuits are fully automated till the

packaging. Yet the packing of snacks to the cartons are still done manually. This particular section remains a grey area to be addressed as it is untouched by automation in most probably all the industries involved in the manufacturing of food products.

2. Literature Review

Eren Demirkol et.al, in their review article analysed the mass transfer parameters namely changes in mass flux, diffusion coefficient and mass transfer coefficient during baking of cookies [1]. The increase in trade rate of ready-to-eat food like cookies highlights an enhanced interest in the investigation of quality defects. The non-homogenous moisture distribution is the key parameter which was victimized due to diffusion and external convective mass transfer coefficient. Thus to make the baking process efficient, it is mandatory to control the mass transfer parameters. The tests are conducted in 2 ways, one is the infinite external convective mass transfer coefficient and the other one is the finite external convective mass transfer coefficient at 190, 200 and 210 degree Celsius respectively. Generally baking is a complex process which results in a series of physical and chemical changes in a product. The baking time and the temperature at which the baking takes place play a very vital role and for different type of cookies the time ranges from plus or minus 6 – 10 minutes and the temperature varied from 180 – 200 degree Celsius. Thus the study has been carried out by analysing the problem one by practical testing with variation in parameters and theoretically feeding the values after which a graph has been plotted taking baking time in x-axis and concentration ratio in y-axis. The results concluded are that while baking the cookies it must be properly monitored that the diffusion and the mass transfer coefficient must be constantly maintained so that even distribution takes place in cookies to obtain high quality. Subir Kumar Chakraborty et al. studied the influence of process parameters in optimizing macro surface textures and overall acceptance of millet rich biscuits using RSM [2]. Five different combinations of refined wheat flour and cereals are used to prepare biscuits by varying time limit in the range of 3.3 – 6.7 minutes and temperature in the range of 166.6 – 183.4 degree Celsius. Evaluation has been done in surface properties such as crispness of the biscuit, hardness of the outer epidermis, strength and most importantly overall acceptability level. After the tests the optimum values founded are 90% RWF, 6 minutes baking time, 170 degree Celsius baking temperature and the crispness, hardness, cutting strength and overall acceptability are 45, 0.3N, 27.2N and 8.9 respectively. The tests are carried out by manufacturing the biscuits in various proportions of the RWF and the millet concentration as they are baked under different temperature and the baking time also was varied based on the proportion of the wheat and millets taken and a detailed analysis is carried out using mathematical tools and various graphs are plotted to analyze the performance and characteristics of the biscuits of each parameter. Several graphs are plotted between factors and responses such as for crispness, between blend ratio and baking time, for hardness, between baking time and baking temperature, for cutting strength, between baking time and baking temperature and for overall acceptability, between blend ratio and baking temperature. Finally, result concluded is that the RWF is the predominant factor influencing the responses. Increasing the weight % of RWF contributes to increased crispness, OAA and cutting strength and reduced hardness value of the biscuits. Dietary fibre enhanced biscuits are known to be showing very low resistance for snapping during textural analysis. Parul Singh et al. optimized the process capability in high fibre and high protein biscuit [3]. Biscuits are processed from sorghum seed powder and finely ground wheat flour with the addition of edible spirulina powder, now commonly available to produce biscuits, which are fibrous and having high protein content. Different levels of these ingredients in biscuits are taken for optimization with its textural, sensory and antioxidant characteristics to be factors. Sensory attribute included colour intensity, flavor, sweetness, graininess, crispiness. Textural attributes included hardness, fracturability and Antioxidant attributes such as DPPS and ATBS inhibition. Evaluation from various tests indicated that amongst the various parameters, the weight % of spirulina algae powder and sorghum seed flour are significantly influencing the responses. Under observation, it is identified that Spirulina, being a rich source of minerals, vitamins and essential bodily pigments is mainly vital for the antioxidant activities producing health benefits upon periodic consumption. Sorghum millet is the main food serving people over a wide geographical area particularly in dry regions. The objective of this study is to determine the effects of various process parameters on the edibility of biscuits. The tests are carried out, a graph is plotted between spirulina powder and sorghum flour to analyze the DPPH and ATBS inhibition and is concluded that the percentage composition of spirulina powder in biscuit increases its protein and mineral content as well as improves immunity. The proportion of sorghum flour in addition to wheat flour in biscuit makes it fibre-rich as well as changes the rheological behaviour of biscuit dough and taste of biscuits. Kevin Cronin et al. conducted a statistical analysis on biscuit physical properties affected due to baking [4]. The quantitative changes happening in the dimensions, mass and hydrous content during post processing of commercial and test grade tea dip biscuits are investigated. An elaborative study has been conducted drawing parallel comparisons between piece weight and thickness of the dough and that of resulting cookies. The sensitivity of the salient properties of the biscuit to the variations in the baking process and amount of dough ingredients is analysed. Based on the above mentioned studies, it is found that the weight distribution in the biscuit is primarily due to the evenness in dough piece weight, which is further linked to spatial differences in the thickness of the dough lamina from where the pieces are cut. During baking in the oven, the weight is further reduced in the biscuits as the moisture content remaining in the dough evaporates due to heat. The fact is the wet dough pieces at higher moisture levels dry more evenly compared to those at lower moisture levels. The moisture level in biscuits is more sensitive to the deviations in oven temperature. After the preparation of biscuits is done, the effective parameters such as dough piece weight, dough thickness, biscuit weight, apparent weight loss, baking temperature and dough piece moisture level are analysed and shown in graphical representation with one versus the other among them. Finally, it has been concluded that the properties like weight, thickness and moisture content of the biscuits are normally

varying 2 - 5% from one piece to another and moisture content of the biscuit prove to be sensitive to deflections in oven temperature as well as directly proportional to dough piece moisture level though it seems less significant commercially.

Rafael Gaildi Salvagni studied the burning rate flame geometry and temperature of convective controlled circular diesel oil pool fired under air cross flow conditions [5]. He presented the investigation of the diesel (s500) type under cross flow conditions and the aerodynamic channel for testing measurement techniques including analysis of infrared image of pool fire, mass burning rate, flame geometry, etc. as a function of cross flow conditions. The study developed for the cross flow velocity range from 0 to 4 m/s. The terms 'convective controlled' referred to the feedback of heat to the pool surface. Ferrero et al. studied the large pool in the open air in natural air considering only the stability of the wind interval. The gasoline and diesel are distributed in the thin layer of 15-25mm. For the study, the MATLAB algorithm, thermocouple, video camera are used. The flame geometry from post process record is immensely affected by the air cross flow. Flame tilt angle initially increases with velocity, then slightly decrease before it becomes constant finally. Flame height first decrease and then increase and become somewhat constant. Thermal behaviour of flame of cross flow is also studied using thermocouple. The flame length first decrease with velocity immediately then cease to become nearly constant. Most recently, a paper has been published based on various studies done in Baking oven [6]. The key elements in this experiment are radiation, convection and conduction in direct gas fired, indirect radiant, hybrid and conventional convective type oven. The burner phenomena are diesel, oil, temperature, humidity, moisture content, baking time, wire-mesh bands and steel bands. In this study the wire-mesh band or carbon steel band conveyor is used. The conveyor band is driven by different speeds for different baking time. As a result, the oven design for heat transfer is optimized through the dough pieces in different ways. In the diesel oven, the heat is transferred to a heat exchanger.

The different types of oven used for baking and the heat transfer mechanisms behind them are studied. The suitable oven for the process is found to be the direct gas fired oven, that provides radiant heat over a large range of input heat energy and suitable for all bakery products. Indirect fired oven provides stable radiant heat and preferred for all processes. In convective type oven, baking is done by blowing hot air into it. This oven relatively has low construction cost. Surendra Singh studied about the energy conservation in biscuit industries [7]. The study is about the energy audit of heat energy undertaken by the biscuit. The key parameters like audit, stack, thermal mass flow rate, enthalpy, energy, pay back, etc are taken into account. The focus is mainly on cost reduction and increasing the utilization of the energy from the flue gas circulating inside the baking oven. By conducting various experiments, the critical parameters which influence the baking process were identified which were influencing the baking. The energy that is recovered from the waste flue gases can be used again. The study identified that varying the mass flow rate could also lead to the conservation of energy in the oven. The study is fully based on the high speed diesel (s500). At the conclusion of the study, the optimized oven temperature, mass flow rate of diesel, enthalpy distribution in oven and the temperature of the baked items are found at the end of the experiments. The better solution to conserve the energy in oven and cost reduction in diesel burner is suggested. The study also covered the comparison of diesel and kerosene usage in the process of baking. Eric Masanet reviewed the energy conservation and cost effective possibilities in the baking industry [8]. According to this study, the U.S baking industries are engaged in the manufacturing of commercial pastries like cookies, bread, cakes, and pies and crackers as a little over \$800 million worth of these are purchased every year. Energy efficiency improvements are important in cost reduction and increase the predictable earnings of the industries. There are varieties of opportunity available in individual plant to reduce the energy in the cost effective manner. Typical measures to be taken in return on investment period and references to further possibilities are discussed in various technical literatures. Methodologies for improving the optimum utilization of water at the plant level is also provided. The data and facts given in this energy guide is very much useful in managing energy needs effectively in various U.S industries thereby reducing the need for power and water considerably, without compromising the quality of the products.

This energy guide provides the best possible technology to harness energy and water efficiently and effectively. Preliminary estimation of energy saving and energy related costs have been provided that case study data from the real world application. Surendra Singh presented a detailed overview about the Oil conservation in biscuit industries [9]. The key elements used here are waste heat, enthalpy, tunnel oven and mass flow rate. Oil used for the experiment is high speed diesel. In this study, it has been noted that a lot of heat energy is wasted in the oven. The waste energy, if conserved per hour will be enough to bake the cookies without moisture. The amount of heat energy present in the flue gases and outlet temperature of the flue gases are also studied. The length of the tunnel oven is modified from the existing 30m to 150m. After doing that, so many analyses are carried out and the optimum mass flow rate of flue gases and enthalpy distribution are found out. By implementing these values in the factory, the cost spent in the fuel is reduced and the complete utilization of energy from the waste flue gas is ensured. The best possible solution for the optimum utilization of fuel economy and recovering of the energy in the oven are identified as conclusion. The study gave a suitable new modification in oven to reduce the amount of fuel consumption. J. S. Das, in his research paper reviewed the application of Robotics and automation for packaging in the confectionery industry [10]. The confectionery packaging is frequently accomplished manually, resulting in wastage, injuries and hygiene issues. As the confectionery market is highly seasonal and competitive with customer demanding unique products and innovative package, the cost of offerings, gifts and their promotion activities are borne by the manufacturers. So the manufacturers have to concentrate on lean manufacturing, increasing productivity, reducing waste, utilising labour effectively and reducing machine downtime. The above process is generally more expensive that adds to the

cost of the final product when an expensive seasonal labour supply is required. Automation with versatile packaging system is proposed to reduce the above problems. The review contains the market trends of confectionery industry and its packaging needs and about the reconfigurable mechanisms and the potential for flexible packaging automation. He developed automation technology with variety of carton folding in reconfigurable system and automated packaging system that describes robotic demonstrator system and helped to create reconfigurable production line that meet challenges faced in the confectionery and food industry.

N.Kondo wrote about the importance of Robotics and automation in the fresh produce industry. The automated grading of fruits and vegetables are already available years ago. The author insists development of implementation of machine vision, sensing systems, robots and PCs [11]. The automation is incorporated in post harvesting section where heavy, dangerous operations to do. The concern is about the quality of food problems includes food poisoning by bacteria, illegal unregistered chemicals and lack of product authenticity. The inspection method should be done by non-destructive manner. Sensors has been developed to assess the feature relating to internal quality including sugar content, acidity and rind puffing, rotten core and other defects. He explained the machine vision, a fundamental component of an automatic grading system with specific reference to four automated post harvesting system and a traceability system for food safety and security is described based on the technologies of data collection and utilization of grading facilities. So the product information and operation history leads to food with a higher level of safety and security data can be helpful in food traceability and provides guidance to develop the precision agricultural systems. P.G.Berrie et al elaborated the relative importance and necessity of Sensors for automated food process control: an introduction. The measurement of process helps not only for monitoring and controlling a process and providing quality unaffected by the operator but also key to reduce capital in inventory and effective energy usage along with the management of assets both at process and enterprise is gaining in importance [12]. Quality, of course lies in the eyes and taste buds of the customers. The quality lies in greens, organically grown vegetables and nutritional values in greater amount. Along with them, the taste and quality in consistent in varieties. Another factor is cost reduction. Reduced cost with greater quality is the ultimate expectation of the customer. This can be achieved by the implementing automation and sensors instead of manpower from the measurement of stock level to the final quality checking. Development for hygienic, reliable instrumentation led to more in-line analysis instruments, allowing automation of the corresponding processes.

Finally, the user has a number of possibilities to integrate intelligent instruments into automation systems, allowing their full potential to be used. Abhijit Suprem et al studied the various technologies incorporated in farm produce and presented a detailed survey entitled "A review on the application of technology systems, standards and interfaces for agriculture and food sector". In that study article, he decreed that traditionally, agricultural industry has been solely dependent on human labour with limited application of mechanical equipment and machines [13]. The applications of technologies such as embedded computing, robotics, wireless technology, GPS/GIS, and DBMS software's are seen to be recent developments. The process of automation in terms of application of mapping technology, sensor network, technology interfaces and methods in agriculture and decreases the challenges. The design attributes such as modularity, flexibility, scalability, extendibility, programmability, integrability, configurability and interoperability are the key concerns in developing the new innovation technology systems for agriculture and food. Sasha V. Ilyukhin putforth a survey of automation practices in the food industry [14]. For the past few years, the food manufacturing sector has experienced a rapid growth and contributed more in the economy. Although food sector contributes more, it is slow to adopt new technologies. Many segments in the food industry operate under seasonal schedules and at low profit margins. These constraints reinforce the need to cost justify any capital expenditure in manufacturing equipment. The food manufacturing sector faces some constraints that are not faced by the others which include the use of perishable raw materials of variable composition, the technical difficulty and expense of sensing food properties online and the availability of skilled employees. The survey stated that all of the food manufacturers automated the process and keep electronic record keeping devices. The level of automation is extremely variable and have a very high desire for technological progress. Equipment suppliers and the system integrators should combine their efforts to provide complete automation plans for the food industry. Two main parameters to be considered are the cost of the offered equipment and services, and change of management philosophy of the food industry towards process automation.

3. Research Gap

The following areas in the manufacturing and packaging of biscuits are yet to be addressed:

1. The field survey in packaging sector and its automation are done. The state is that usage of sensors in all opportunities and the implementation of automation and robotics are done. The area of packing the number of products in boxes are not automated yet and it tends to be a grey area, which remains untouched.
2. The field survey regarding the diesel based burners and ovens are studied. The researchers focused mainly on recovering the waste energy like flue gases and developed methods to prevent the wastage of energy by optimizing various nominal and feasible parameters. The optimization of parameters with an approach from a broader perspective that focuses on more amicable applications which increase the effectiveness of the burners rather than simply concentrating on the prevention of loss of energy is not done yet.
3. As observed from the above papers, it is seen that the baking of the biscuits have been studied and analyzed by taking baking temperature, baking time, ingredients, composition of the dough, moisture content and dough thickness as

process parameters. But the source of heat supplied for baking has not been discussed in the above papers whether it is coming from a single point source or multi point source. So it is suggested that, if we consider the above mentioned characteristics, we can ensure the complete and efficient baking of biscuits.

4. Conclusion

From this paper, it is clearly revealed that the manufacturing of biscuits is carried out under three phases namely, optimization of design parameters of diesel fired oven, factors influencing the baking of biscuits and finally the packaging of biscuits. Based on this review the following conclusions are drawn; source of heat influences the quality of baking of biscuits. Air fuel mixture ratio and flame geometry have a great impact over the consumption of diesel. Lot of energy and cost can be saved by utilizing the waste gases dissipated from the oven after baking by recirculating them. By conducting a detailed survey of various journals that are mentioned above, we can have the recommendations of the previous researchers in the form of the following important points for higher efficiency and performance in the manufacturing of biscuits: Flue gas can be recirculated. If the process parameters such flame length, flame width, furnace temperature, air fuel mixture and burner design are controlled, then the usage of diesel can be optimized. The source of heat for baking must be determined. If we want to optimize the parameters essential for the effective baking of biscuits, then it is mandatory to set the proper source of heat for the baking of biscuits first. If we calculate the number of packets to be allocated in a carton by calculating its areas, we can ensure that the automation in packaging of biscuits can be achieved.

References

- [1] Demirkol, Eren & Erdoğan, Ferruh & Palazoğlu, Tunç (2006), Analysis of mass transfer parameters (changes in mass flux, diffusion coefficient and mass transfer coefficient) during baking of cookies, *Journal of Food Engineering* (72), 2004, pp. 364-371, DOI:10.1016/j.jfoodeng.2004.12.016.
- [2] Chakraborty, S. K., Kumbhar, B. K., Chakraborty, S., & Yadav, P, Influence of processing parameters on textural characteristics and overall acceptability of millet enriched biscuits using response surface methodology, *Journal of food science and technology*, 48(2), 2011, pp.167–174.
- [3] Parul Singh, Rakhi Jha, Alok Rasane & Prasad Gautam, Optimization of a process for high fibre and high protein biscuit, *Journal of Food Science and Technology –Mysore*, 2013, DOI: 52. 10.1007/s13197-013-1139-z.
- [4] Cronin, Kevin & Preis, Claudia, Statistical analysis of biscuit physical properties as affected by baking, *Journal of Food Engineering* (46), 2000, pp. 217-225, DOI:10.1016/S0260-8774(00)00053-4.
- [5] Salvagni, Rafael & Centeno, Felipe & Indrusiak, Maria, Burning rate, flame geometry and temperature of convectioncontrolled circular diesel oil pool fire under air crossflow conditions, *Journal of Hazardous Materials* (368), 2019, DOI: 10.1016 / j.jhazmat . 2019. 01.087.
- [6] Johannes Haas, Josef Haas, Stefan Jiraschek, Erich Koletnik & Johann Sachsenhofer, Baking Oven, *US Patent Number*, 9854812, 2018.
- [7] Surendra Singh, S.B.Gupta & Abhay Kumar Sharma, Energy Conservation Analysis in Biscuit Industry, *International Journal of Advanced Research and Technology (IJAERT)*, 2014, ISSN: 2348-8190
- [8] Therkelsen, Peter & Masanet, Eric & Worrell, Ernst, Energy efficiency opportunities in the U.S. commercial baking industry, *Journal of Food Engineering* (130), 2014, pp.14–22, DOI:10.1016/j.jfoodeng.2014.01.004.
- [9] Surendra Singh, Oil Conservation in the Biscuit Industries, 2012.
- [10] Dai, J.S, Robotics and automation for packaging in the confectionery industry, *In Robotics and Automation in the Food Industry*, 2013, pp. 401-419, Woodhead Publishing.
- [11] Kondo, N, Robotics and automation in the fresh produce industry, *In Robotics and Automation in the Food Industry*, 2013, pp. 385-400, Woodhead Publishing.
- [12] Berrie, P.G, Sensors for automated food process control: an introduction, *In Robotics and Automation in the Food Industry*, 2013, pp. 36-74, Woodhead Publishing.
- [13] Suprem, A., Mahalik, N. and Kim, K., A review on application of technology systems, standards and interfaces for agriculture and food sector, *Computer Standards & Interfaces*, 35(4), 2013, pp.355-364.
- [14] Ilyukhin, S.V., Haley, T.A. and Singh, R.K., A survey of automation practices in the food industry, *Food Control*, 12(5), 2001, pp.285-296.