Innovative gutter conveyor for delicate products in food technology

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Summary

Customer satisfaction has become the basis of the production philosophy in the food processing industry. The quality of food and products offered is a key criterion which has an impact on consumer decisions, while the total product quality is made up of its brand, price and packaging. The total product quality also refers to factors which ensure guaranteed characteristics of the products, measured through the introduction of fruit production and packaging standards. The most important guidelines in this respect, from the point of view of the fruit and vegetable processing technology include:

- GMP (Good Manufacturing Practice),
- GHP (Good Hygienic Practice),
- HACCP system (Hazard Analysis and Critical Control Points) and quality management systems.

Frequently, BRC (British Retail Consortium) and ISO -9001/9004-2000 systems are also implemented in companies. The HACCP and GMP systems are oriented towards meeting technological requirements during the production of foodstuffs, while ISO systems focus on complying with the product quality. The above-mentioned regulations are aimed at combining technological and organisational requirements in order to ensure appropriate food quality and customer safety, meet the legal requirements, limit the occurrence of defects and guarantee good product manufacturing. (Ellen van Kleef, et al., 2005).

Chapter 1 presents the objectives of the implementation work, which take into account the needs of the market for the transport of fragile products. Irrespective of the size of the plant and the production volume, the appropriate selection of the conveying equipment determines, to a great extent, the performance and efficiency of production lines. Food processing plants have, as a rule, high processing capacities. The capacities of food processing plants can reach even up to several tonnes per hour (including potato processing plants which produce potato starch). The specifics of material movement vary considerably, depending on the type of load in different industry branches. Raw materials and food products are often characterised by increased acidity and alkalinity. They are classified as perishables and require special attention during storage, process operations and transport activities (Błasiński, et al., 2001).

Chapter 2 analyses the issue of damage to fragile products in food technology. Micro-cracks which appear in the raw material structure increase the production costs, speeding up the product degradation in the subsequent stages of the technological process, and as a consequence of this, require the removal of the defective product from the manufacturer's offer after the completed production cycle. Unit processes implemented in relation to raw materials are analysed in the food processing technologies so as to optimise the production by selecting the appropriate method of product dosing. Analysis of unit operations leads to the shortening of the time of operations to the necessary minimum, so as to limit the probability of mechanical damage. This leads to a reduction in the waste mass. At the same time market requirements set by consumers impose frequent changes in assortment, force manufacturers to use conveying equipment which enables the quick line changeover for a new product type. The designed trough conveyor meets stringent requirements related to the transport of fragile products, significantly reducing the mechanical damage.

The implementation work on the trough conveyor was divided into several stages.

The first stage, presented in chapter 3, consisted of the performance of analysis of the types of in-plant transport used so far in the food industry, with a particular consideration of shaker (inertial) conveyors. The designed conveyor belongs to the group of vibratory tension member conveyors, in which the loose material moves in a trough as a result of inertia forces. The material located in the trough performs continuous short slides, overcoming the static friction forces and the forces which interact with the raw material. During the movement in the conveyor trough, additives resulting from the production technology are introduced onto the surface of the conveyed raw material. Analysis of expectations of the customers – manufacturers of processed consumer goods has demonstrated that they expect technical solutions and process (food) safety requirements which may only be fulfilled by the tension vibratory member conveyor which is not yet offered on the Polish market.

The second stage involved the performance of simulations and tests on a provided test stand, which consisted of the vibratory tension member conveyor. The test stand made it possible to analyse the impact of process parameters and selected features of the conveyor on the efficiency and quality of the conveyed raw material. The research programme following from the changes introduced in the design at the prototype stage as well as from the testing of the quality of the raw material included:

– analysis of the impact of the material/raw material texture on the design guidelines of the conveyor trough;

- the behaviour of the raw material taking into account the impact of the slide (friction force) on the trough;

- the impact of the device on the environment (vibrations, dust, energy aspects of the process).

Available numerical methods, which allow for the studying of the behaviour of particles, enable machine constructors to perform calculations of forces interacting with the material conveyed. The Discrete Element Method (DEM) has been used in this paper. It enables the performance of simulations of motion of any particle shape in a conveying device. Chapter 4 presents the advantages of the DEM modelling and also provides a literature review regarding the DEM simulations performed so far in agriculture and food industry The DEM uses the assumptions of the Lagrange computational model in which each particle in the domain is tracked individually. This enables the thorough study of the behaviour of the whole deposit of bulk material which consists of the set of elements that have characteristic physico-chemical properties. The deposit was, therefore, not considered according to averaged and fixed values, e.g. strength values, but rather as a set of elements that can be described individually. The most important ones are normal forces and tangential forces resulting from the collision of particles with the walls of conveying devices. They mainly affect the quality of the conveyed raw material.

Simulations of mechanical impacts during transport were performed using the RockyDEM® software manufactured by Engineering Simulation and Scientific Software Ltda. The software uses the Discrete Element Method (DEM). Chapter 5 contains the description of the RockyDEM® software which provides possibilities for conducting simulations of motion of any set of particles of any shape, moving in the conveying device. Chapter 6 describes mathematical models used for simulation calculations, which allowed for the presentation of the movement of a deposit of conveyed raw material, corresponding to the real processing conditions. And chapter 7 presents mathematical models of analysed normal and tangential forces resulting from interactions on the particle surface.

Chapter 8 shows the simulation results related to the transport of blueberries, using the discrete element method (DEM). The impact of the type of the conveying device on the values of normal and tangential forces which occur between the blueberries and the structural elements of the conveying device, as well as interactions between the fruit were modelled. Additionally, an analysis of

the particle collision energy spectrum was performed. It allowed for the determination of the probability of damage to the fruit during transport and identification of the phenomena that are conducive to this, based on the amount of energy absorbed by each fruit as a result of collisions.

Chapter 9 presents the stage of research using the constructed test stand, which included an analysis of the impact of the trough surface of the designed trough conveyor on the values of the mass output of conveyed raw materials/products. Additionally, optimal settings of the trough conveyor parameters were determined taking into account the characteristics of the conveyed product. The tested product which was transported on the designed trough conveyor was the blueberry fruit. During research work, attention was also paid to the behaviour of the transported product and the quality of the product depending on the length of the conveyor trough and the height of the product layer on the trough.

Analysis of simulation and test results as well as final conclusions were presented in chapter 10. The research was concluded with the determination of optimised mechanical parameters for the device, taking into account the efficiency of the process as well as the physico-chemical and morphological properties of the transported product. At the stage of design of the trough conveyor, also initial design assumptions such as the capacity of the conveying device, the direction of movement of the raw material, the aesthetics of performance and the ease of maintaining the device in cleanliness were also taken into account.

The constructed prototypical device was presented during industry fairs, i.e. SyMas in Cracow, WARSAW FOOD TECH in Nadarzyn and POWTECH in Nuremberg.

The third stage, presented in chapter 11, which concluded the implementation work was the preparation of detailed documentation, operation and maintenance manuals, risk analysis and product card for the innovative trough conveyor, taking into account the results obtained during the research work. Additionally, during the third stage, a marketing campaign was launched to inform about the possibility of purchasing the innovative trough conveyor bearing the trade name KRYS. (Mysak Group, 2021)