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Quantitative analysis for peach production line management

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ABSTRACT

The quantitative analysis, including reliability and maintainability which are of the fundamental issues for the operation management of an automated peach production line, was developed. Descriptive statistics of all the failures at machine and line level were shown, and the most critical machines under failures according to several criteria were determined. The best fit of the failure data between the common theoretical distributions was found and the respective parameters were identified. Moreover, the reliability and hazard rate models for the entire production line were calculated. They both proved to be useful tools to assess the current situation, and to predict reliability, mainly in short term, for upgrading the operation management of the peach production line. It was pointed out that (a) the mean time-to-failure (TTF) is approximately 650 min whereas the mean time-to-repair (TTR) a failure amounts to approximately 70 min. (b) The failure times follow the logistic distribution whereas the repair times comply with the Weibull distribution, and (c) the repair rate of failure is increasing, thereby implying that the maintenance staff expertise increases with time.

1. Introduction

The operation management for the modern food production lines plays an important role on the productivity and quality of the products. Markeset and Kumar (2003) considered the need to compensate for product un-reliability, loss of product performance, reduced product output quality and lack of usability. The reliability is the main factor for the equipment of the production line that affects directly the system performance, and has significant economic impact on the company (Bloch, 1998). Failure intensity increases with equipment aging; therefore, the equipment requires continuous monitoring and immediate technological repair. Pidgeon and Leary (2000) estimated that complex system failures highlight organizational factors in the triggering of accidents and disasters across a wide variety of settings. According to Kumar and Pandey (1993), "during operation, various systems of the plant are liable to fail in a random fashion. The failed subsystem can however, be back into service after repairs/replacements. The failure rate of the subsystems in the particular system heavily depends upon the operating conditions and repair policies applied." Kostoglou et al. (2004) presented the investigation of various issues of human resource management adopted by the enterprises for upgrading the productivity.

In literature, many researchers have discussed the reliability of several processing industries applying different techniques. Michelson (1998) discussed extensively the use of reliability technology in the process industry. Jones and Hayes (1997) have proposed a methodology for collecting field data and their analysis for assessing the current reliability of a given production on line. Habchi (2002) improved the method of reliability assessment for suspended test which is performed in order to accelerate testing duration and then to obtain information quickly on the life distribution of products. Weckman et al. (2001) have proposed the Weibull process for modeling complex repairable systems. Kiureghian et al. (2007) analyzed the availability, reliability and downtime of system with repairable components. Moreover, Zhao (1994) developed a generalized availability model for repairable component and series system including perfect and imperfect repair. Blischke and Murthy (2003) suggested that since failure cannot be prevented 100%, it is important to minimize both its probability of occurrence and the impact of failures when they do occur. Patchong and Willaeys (2001) presented a model where a production line composed of unreliable parallel-machine stages is tackled.

The corresponding literature related to the food industry is quite limited. Tsarouhas (2009) had classified and calculated primary failure modes in bread production line. Tsarouhas et al. (2009) discussed reliability and maintainability analysis of cheese (feta) production line in a Greek medium-size enterprise.

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Liberopoulos and Tsarouhas (2002) reported on speeding up and improving a croissant production line. Moreover, Liberopoulos and Tsarouhas (2005) studied the statistical analysis of failure data of an automated pizza production line.

In this study, a statistical analysis of failure data for the peach production line was carried out. The analysis includes the descriptive statistics of all the failures at machine level, and the most susceptible machines to failure, according to several criteria, were determined. The best fit of the failure data among the common theoretical distributions was found and the corresponding parameters were identified. Moreover, the reliability and hazard rate models for the entire production line were calculated. They can potentially be useful tools to assess the current situation, and, more importantly, to predict reliability for upgrading the operation management of the peach production line, and other relevant production lines.

2. Materials and methods

2.1. Peach production process

The peach production line is fully automated and consists of equipment in series. In Figs. 1 and 2 the main stages for peach production are shown schematically and the flow diagram of canned peach production line, respectively. The peach production line comprises the following machines:

M1, Bins capsizing: Boxes containing products are placed on transport belt till they reach over tank level where the boxes gradually turn obliquely and their content is emptied in the tank. The later is filled with water for the first wash. Then, the empty boxes are removed by means of a chain transport belt.

M2, Water tanks 1 and 2: The product is thoroughly washed in two water tanks. Thus, the foreign materials, included in the product over harvesting, are removed. The water in tank remains pure by being continuously renewed (Lozano, 2006). In this stage the fruit undergo quality control as well. The fruits are transported on a belt and trained personnel remove the defective fruits from the production line. The soft, and infected and green fruits are thereby separated.

M**3**, Whole fruit grading: The fruit are transported to a mechanical grader which grades the fruits based on their diameter. This machine consists of a belt with openings (gaps) of different size. The belt revolves continuously and the fruits enter in gaps pending their size and move to new transport belts classified in three categories; small, medium, and large size (Siddiq, 2006).

M**4**, Coring/de-pitting: Peach coring/de-pitting is carried out with automated pneumatic machinery. The peaches core is placed in the center of a horizontal and vertical axes of the rotating mechanism. Adjustable blades rotate to easily cut halves or quarters. The pit is removed, loaded on a silo and used as fuel (Amori, 1972).

Halves (peaches) are checked with regard to effective de-pitting when transported on a belt. After the electronic and visual control of halves for checking the removal of core, the halves still containing core will have to go through the process again in order to ensure the proper removal of pit.

M**5,** Peeling: Peeling is the process aiming at removing the peel from the fruits and takes place in a machine called "*peeler*", at 90 °C. Fruits are transported on a belt above which there are recipients with dilute NaOH solution (SEPA Technology Transfer, xxxx; Stone, xxxx). The overflowing solution will come in contact with the fruits. The NaOH solution is placed in the tank close to the de-peeler. The solution is vapor heated to reach 90 °C (Masanet et al., 2008). The dilute sodium hydroxide solution is collected at the bottom of the peeler for recycling purposes. After peeling, the fruits are washed with pressurized cold water to remove any peel remains on the fruit meat.

M**6**, Washing with water: The fruits are thoroughly washed in a water tank.

M**7**, Cup up and cup down control: The halves are mechanically capsized by means a stainless steel equipment so that they are cup up. The halves are checked for potential defects (pit remains, openings due to insects, bruises etc.). Then the halves are turned upside down and checked for the presence of peel residues, black stains or other defects. The defective items are removed from the production line.

M**8**, Grading of halves: The fruits are transported to halves grader consisting of tilted level with holes whose diameter increases gradually. Halves grading is made in any of the following categories; 52, 54, 56, 58, 60, 62, 64, and above 64 mm.

M**9**, Cube/slice cutter: Although peaches are often cut in halves, on some occasions they are cut in slices. The highest demand, however, is for peach cubes for salads or addition to other food such as ice-cream, yogurts, cakes, sweets, etc. Halves to be cut in slices go through a machine with five knives thereby producing six slices (Masanet et al., 2008). The other parts of halves go through a cube cutter consisting of a square frame. The fruits are pressed against the square frame by a piston. The fruits cut in slices are placed on a transport belt and trained workers do the final checking based on quality criteria.

M**10**, Magnet: All peach products (halves, slices, cubes) are introduced in a tunnel with a magnet. More specifically, the magnet is placed on transport belts to remove any ferrous material/particles from the product.

M**11**, Fruit filler: The empty cans are vapor sterilized and are transported to the filling station. The fruits go up by means of an elevator and placed in the filler. The fruits filling in the cans is

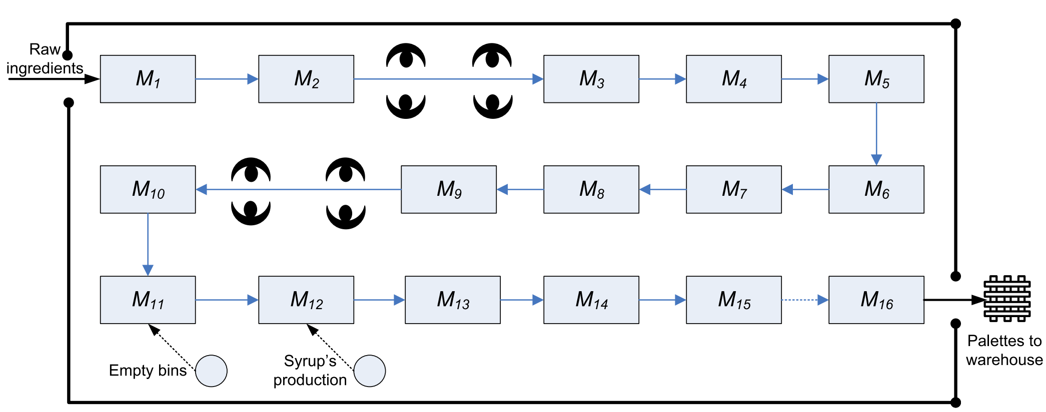

Fig. 1. Schematic presentation of peach production line.