Analysis and improvement of the quality levels perceived by the consumer through the control of internal variables related to the process and the product

Sara Isabel da Conceição Dias,
Instituto Superior Técnico, Lisbon, Portugal
May 2014

Abstract
The present study was developed with the intent of analyzing and improving the levels of quality perceived by consumers of biscuits produced at the Mem Martins plant, from Mondelēz International.

This study began with the analysis of the complaints received in the factory, concerning the cookies produced in here, in order to identify focal products and categories of complaint. It was concluded that most complaints were related with Yayitas Mel, in the categories of undercooked and abnormal taste, and with Ritz Original, in the categories of broken, undercooked, with stale, rancid and salty taste. Further analysis throughout time led to the conclusion that the corrective actions already implemented at the production line of Yayitas managed to offset the causes of complaint, with no complaints for this product at the time of this study. Therefore, this study focuses on analyzing complaints on Ritz Original. In an attempt to validate and to find complaint sources, so that it could be acted on the areas of opportunity, several analyses regarding different aspects of the production line and of the product took place. It was concluded that the level of breakage was actually higher than maximum allowed by the specification. After changing the equipment with higher impact on the breakage, the situation was solved. For complaints in the taste category, no source was identified, since the peroxide values of the fat sprayed on the cookies’ surface and of the fat in the cookies were found to always comply with the specifications. Finally, another analysis was also performed in the production line to identify potential situations that could represent a risk of inclusion of foreign material in the cookies. For all these situations, corrective actions and preventive and monitoring procedures ahead of product release were suggested. In that way, the decreasing of the level of quality perceived by the consumers is avoided.

Keywords: cookie, food industry, quality, quality perception, complaint.

1. Introduction

1.1. Contextualization
This study begins with a chapter about Mondelēz International, with special attention to Mem Martins plant and how the Quality Department handles the complaints received. After that, comes a theoretical review chapter, which addresses the issues of industrial production of cookies and quality in the food industry, presenting some quality tools and methods. Then, the complaints received from January to October 2013 were analyzed, taking into account their absolute number and then, taking into account the quantity vs. quantity produced (CPM), in order to identify the products with more complaints. After that, the complaints were organized and analyzed in order to identify the categories and subcategories that represent the focal of complaint. Subsequently, these data was compared with notes of nonconformity in the plant. In the following chapters, the materials and methods used in the analysis of focal categories of complaint, previously identified, were presented, proceeding then to the analysis and discussion of the results, corrective actions and preventive and monitoring procedures ahead of product release are suggested, avoiding the decrease of the level of quality perceived by the consumers.

1.2. Mondelēz International
Mondelēz International is Europe’s largest chocolatier and biscuit baker, the second-largest maker of candy and coffee and the third largest producer of gum. Launched in October 2012, this company comprises the former billionare brands of Kraft Foods, Inc., as Milka, Toblerone, Jacobs, Tassimo, Carte Noir, LU and Oreo, 25 of these with more than 100 years. Mondelēz International has operations distributed in more than 80 countries and markets its products worldwide, with global net revenue of $35 billion in 2013. In Portugal, Mondelēz International is found as one of the 10 largest food and beverage companies [1].

Mem Martins Plant
Built in 1979, Mem Martins plant covers 56 000 m² (19 500 m² of built area) and employs about 100 people, mostly in the production roles. Located at 30 km west of Lisbon, it works at 48% full capacity, producing annually 15 000 tons of biscuits. It is divided currently in 5 production lines which work continually, in shifts, according to the needs of production, ensuring the production of different types of cookies from different types of dough (3 production lines for hard dough and 2 for short dough), with different types of formation (rotary mould, lamination and cutting wire), and different technologies for packaging (vertical wrapping, horizontal wrapping, flowpacks, manual packaging and rolls) [2].

Quality levels perceived by consumer
The company encourages the customers to communicate with it, either to express a suggestion, to request information, to congratulate or to make a complaint, contributing to a policy of continuous improvement. To this end, in each package there is a contact number, an address or an email. Also, it is available, on the company website, a contact area with a form to the same effect. A complaint can be defined as any expression of
dissatisfaction with a product or service. The complaint management allows Mondelēz International to recognize the quality level of its products perceived by the customer [3].

All business areas of Mondelēz International have a department that provides an interface between the company and the customer, the Consumer Services Centre. This department has people hired externally, with specific training in communication, responsible for receiving the complaints and to respond to them, always respecting local policies and reflecting the attitude of Mondelēz International. The Consumer Services Centre registers the complaints in a database called VOICE (Vision of Insights via Consumer Experiences), classifying and guiding them to the plants responsible for the production of the claimed product [3].

When complaining, the customer has to provide some information about the product, including the lot number.

When complaining, the customer has to provide some information about the product, including the lot number.

The lot code currently in use is a set of characters (letters and numbers) which identify the plant, the production line, the year, week, day, and shift of production, ensuring the traceability of the product. In Picture 1-1 is an example of a product produced on 8 December 2013, that is, on day 7 of week 49, 2013.

Identified the product of complaint, the Consumer Services Centre classifies it by category and subcategory. Examples of main categories of complaint are appearance, texture, taste, odor, foreign material, packaging quality and quantity of product. The sub-categories are associated with each main category. For example, the appearance category can be subdivided into broken, abnormally colored, burnt appearance, oily appearance, small, etc.. Subsequently, complaints are handled by the Quality Manager of the plant that gathers process data from the days of production, records of quality control, stored products in shelf life and other information that might be relevant to identify the source of the complaint. If necessary, the Quality Manager can implement procedures and corrective actions to eliminate potential causes of nonconformity [3].

1.3. Biscuits, cookies and crackers

The word “cookie” comes from the Latin panis biscoactus, and means bread (panis) twice (bis) cooked (coactus). Cookies were once very simple, baked only with flour and water. The double-baking process conferred a low level of moisture, disfavoring the development of microorganisms, thereby increasing its shelf life. If these biscuits were very unattractive being made from more or less flour and water, nowadays the words “biscuit” and “cookie” are related to a variety of staple foods. However, these continue to be based on flour and still have a long shelf life (as long as they are protected from oxygen and atmospheric moisture). The appeal of cookies spans all ages and occasions. Therefore, they represent a large sector in the food industry [4, 5].

Cookies are a unique example of a snack food that, in years past, was a homemade item for most people. The biggest challenge for the cookie industry is to try to accomplish the homemade taste, texture and appearance in the cookies industrially produced. A biscuit factory is typically an extended building, due to the oven tunnels that are usually very long (up to 150 meters in length, although measuring only up to 1.5 meters in width). Before the oven, comes an area where the cookies are formed and, prior to that, an area where the dough is formed and mixed. Near the mixing area, there usually is a weighing room and a storage room for raw materials. Immediately after the oven, there is a cooling area for the baked cookies, sometimes divided into several floors to save space. After cooling, the cookies enter the packaging section, where they’re normally packed by automatic high-speed machines. There are cookies that require secondary treatment, such as the application of heat-sensitive covers, like chocolate. Beyond these areas, there are auxiliary units such as warehouses of equipment and finished product, offices and all other logistic units [4, 5].

The classification of biscuits in different categories poses some difficulties, taking into account the definitions of biscuit, cracker or cookie that overlap each other. In general, all designations refer to a flour-based product enriched with fat and sugar in various proportions. There is a whole range of other ingredients according to the recipe and the cookie to be produced. Another difficulty is related with the amount of characteristics that can be used to separate the biscuits into different categories. Currently, the cookies can be distinguished taking into account the amounts of fat, sugar and flour that form its dough, the method of preparation and forming the dough or, its appearance, texture and consistency in the end of the process [4].

The constitution of the dough has great influence on its rheological behavior. Dough poor in sugar and fat forms, during the mixing, a three-dimensional structure of gluten, due to the reaction of proteins present in the flour with water. This structure confers viscoelastic properties to the dough, which results in a greater extensibility, strength and cohesiveness (hard dough). On the other hand, dough rich in sugar and fat, and consequently not as rich in water, is characterized by being soft, plastic and not extensible (short dough). Taking into account these properties, there are different methods and equipment to handle the dough and to form cookies from these. The formation of dough into cookies, prior to the baking step, is currently done by a mechanized process, which basically mimics what was once done by hand. Examples of formation are cutting, which can be preceded by lamination; rotary moulding or extrusion, which can differentiate in cutting wire, co-extrusion or deposition [4].

Fat and its influence in the taste of biscuits

Fats are one of the most important ingredients in the industrial production of biscuits, incorporated in the dough, or later, applied as a coating. Over time, the lipids present in the fats deteriorate, by chemical reactions with the oxygen in the air,
and form hydroperoxides, which are very unstable and, therefore, precursors of lower molecular weight compounds, many of which with unpleasant tastes. The high temperatures, the presence of unsaturated fatty acids in lipids, the sun light or the presence of certain metal ions, which may act as a catalyst, such as copper, are pro-oxidant factors, promoting the deterioration of fats. To delay and thus minimize this effect, lipids (fats and oils) used in the food industry are typically supplemented with antioxidant chemicals [4].

The rancidity is a severe problem that requires the careful transport and storage of fats and fat enriched cookies. It was not a coincidence that low fat content crackers were the first industrially produced. Precisely by having a low content in fat, crackers are often sprayed with warm liquid oil, shortly after leaving the oven. This procedure enhances its appearance and texture, creating a golden film on the surface of the cookie and modifying the organoleptic properties perceived by the consumer. The lipid used in the cookies must be carefully selected, giving preference to those that are more resistant to oxidation. Among the cheapest and most commonly used are palm oil and coconut oil. However, these oils must be applied warm, since the environment temperature is near to their melting point temperature, which make it dense. Another disadvantage of this procedure is that, when sprayed, the oil converts into small droplets, increasing the surface area available for mass transfer with the oxygen in the air [4].

1.4. Quality in the food industry

"Quality" is a subjective concept, related to the perceptions of each individual. It can mean suitability of the product to the consumer, i.e., satisfaction of the requirements considered essential by him. However, from the point of view of the producer, the product has quality when it is in accordance with the specifications. In most cases, these specifications match or exceed what the consumer requires a minimum of quality [6].

For most industries, it is difficult to always produce products in which all characteristics are always exactly alike. However, if the difference between two products is negligible, it may have no impact for the consumer [6, 7, 8, 9]. For that reason, any stage of the process must be controlled. Each characteristic can assume a desired value of a measurement which is called the "target value". These target values are usually bounded by a range of values that, most typically, are believed to be sufficiently close to the target so as to not impact the function or performance of the product if the quality characteristic is in that range (upper and lower specification limits). Quality control, when installed, has the aim of trying to minimize the natural dispersion of results, since variability is inversely proportional to quality. Variability can only be described in statistical terms and so statistical methods play a central role in quality improvement efforts [6, 10].

PDCA cycle and quality control tools

The statistical process control (SPC) was introduced in the twentieth century by Walter A. Shewhart, who found that statistics of industrial processes could later be analyzed, in order to determine whether the process is under control or, on the contrary, out of control, affected or not by assignable causes. In the 20s, Shewhart proposed the PDCA cycle (Plan, Do, Check, Act), the last step preceding the first in a closed loop with a prospect to continuous improvement the processes. Nowadays, there are seven basic quality tools used in studies of quality control, for instance, in the third step of PDCA cycle. Pareto charts, developed by Joseph Juran, are bar charts where the frequencies of events are sorted, from largest to smallest, thus identifying the most significant causes of the problem recognized in the process. Then, one can focus efforts on the most significant causes, ignoring the minor causes. It also shows the curve of cumulative percentages, with the aim of proving the Pareto principle (also known as the 80-20 principle) which states that, for many phenomena, 80% of consequences stem from only 20% of the causes. The other six tools commonly used in quality control are Ishikawa diagrams (also known as cause-and-effect diagrams), histograms, control sheets, stratifications, scatter diagrams and control charts [8].

2. Analysis of quality levels perceived by the consumers of cookies produced at the Mem Martins plant

2.1. Materials and methods

Complaints for the generality of the biscuits

In order to evaluate the quality levels perceived by the consumers of biscuits produced in Mem Martins, an analysis for all the complaints (in absolute number), received from January to October 2013, was performed, representing them in a bar chart, according to the different biscuits.

Since the rate and volumes of production can vary from product to product, to ensure a comparable analysis between cookies, in addition to the analysis of the complaints in absolute number, a relative number analysis was performed by relating the number of complaints with the number of consumption units produced during the same period of time. A consumption unit (CU) is defined as a unit sold to the consumer. Knowing the number of CUs produced, the results may come in CPM, i.e., complaints per million CUs produced (Equation 2-1).

\[ \text{CPM} = \frac{\text{complaints}}{\text{million CUs produced}} \]

Equation 2-1

It needs to be pointed out that a lot of the cookies produced in Mem Martins are sold outside Portugal. This causes the customer to have contact with the cookies a few months after its production. Besides this fact, it must also be considered that the products may be purchased by the consumer and not consumed immediately and, if the consumer wants to complain, the date of this complaint is always the date of consumption, which might be a few months after production. For these reasons, to calculate the CPM, it is not entirely correct to relate the complaints received between January and October with the CUs produced in the same period. However, since we intend to analyze all the cookies produced in Mem Martins, with different markets (national, European and intercontinental) and different properties, which lead to different shelf life, it is impossible to link the production date with the complaint date for all the different products.

Later on, for the biscuits with higher CPM values, a more detailed analysis was performed, using Pareto diagrams to identify and analyze the different categories of complaint.
2.2. Results and discussion

Complaints for the generality of the biscuits

Figure 2-1 represents all the complaints (in absolute number) received from January to October 2013, for all the cookies produced at the Mem Martins plant.

From the Figure 2-1, it is clear that, from January to October 2013, Ritz Original was the product with more complaints (in absolute number), holding 815 for a total of 1338 (61%). Mini Manteiga, Mini Shortcake and Yayitas Maçã are the products with fewer complaints (in absolute number), holding only 1 complaint in this period.

Figure 2-2 represents all the complaints (in CPM) received from January to October 2013, for all the cookies produced at the Mem Martins plant.

From its analysis, it can be concluded that Yayitas Mel was the cookie with higher CPM values. Although it has only 116 complaints from a total of 1338 (8.7%), as it was produced in smaller quantities, it has a CPM of 171. On the other hand, Ritz Original, that was the product with more complaints in absolute number, has a CPM value of 80. It should be noted that the first three places in the two types of analysis (in absolute number and in CPM) belong to the same products. Given the results, it was decided to study in more detail Yayitas Mel and Ritz Original.

Yayitas Mel

Yayitas represent a family of traditional, sweet and short dough biscuits, which are available in various flavors: honey, apple and chocolate. Yayitas Mel (honey) are golden rectangular cookies formed, with rotary mould, sold in Spain.

In an analysis by category of complaint, it was concluded that 66% of the 116 complaints received were in the category of texture and 31% in taste. In texture, 88% of the complaints received were in the category of underbaked and, in taste, 92% of the complaints received were in the category of abnormal taste.

The complaints, in most cases, can relate with some production event, i.e., changing of a supplier of raw material, of an ingredient or the quantities of this, of equipment or the operating parameters of this may lead to changes in the final product, which can lead to complaints by the consumers. To determine if these complaints could relate with some kind of production event, its frequency over time was analyzed, concerning the date of production of the claimed products (Figure 2-3).

As can be seen in the Figure 2-3, January 2013 is the month with the highest CPM value. Despite being one the months with fewer complaints throughout the year, little quantities of Yayitas Mel were produced. April 2013 comes next, with 292 complaints per million CUs produced. Though the production was almost 6 times higher, there were also more complaints in absolute number. Until March 2014, there weren’t received any complaints for Yayitas Mel since June 2013, although this product continued to be produced (except in August).

By checking the production records, including the ones concerning the baking step, it was noticed that, until May 2013, the moisture values of the product, when exiting the oven, were occasionally outside the specification limits (0.5 - 2.0%). Furthermore, it was found that several baking temperature profiles were experienced during this period.

During baking, moisture can only be lost from the cookie’s surface. For this reason, migration of water to the surface by capillary action and diffusion must occur to enable the cookie’s center to dry. In the oven, heat is applied to the dough piece by a combination of conduction (through the baking surface), convection (from the hot air moving in the oven) and radiation (from the hot surfaces of the structure of the oven). The
cookie’s center is heated principally by conduction of heat from the surface but, as the crust dries, it acts as an insulator and it becomes progressively more difficult to heat the center. Thus, baking is a matter of finding the best conditions of heat and time to allow structure development, surface coloration and drying of the cookie until the desired standards. Moisture values lower than desirable correspond to dry and darker cookies with burned taste as moisture values above the desired correspond to soft texture, not crunchy, light colored cookies that quickly get to the old/stale taste [4].

In June 2013 there was an intervention at the baking temperature profile, changing it from 170/195/185°C to 170/225/215°C. A significant increase in these temperatures led to an improvement of the baking step, which had influence in the final texture and appearance of the product. Besides this change, the exhaust duct of the oven was opened. The exhaust of the air to atmosphere is necessary to relieve the pressure in the oven, allowing moisture loss and expansion of the product. However, with the extraction duct open, the oven has to work at higher temperatures, because it loses some heat to the hot air exhausted [4]. Besides, to facilitate detection of a noncompliance, a visual control with guidelines was created for the cookies exiting the oven.

The analysis of the causes of complaint and its consequent adjustment led to the absence of complaints for Yayitas Mel. Therefore, from this point on, this study focused on the complaints for Ritz Original.

Ritz Original

Ritz Original is a round docker pinned cookie with a laminated texture, belonging to the category of savory crackers, due to salty topping (0.7%) and the sprayed palm oil (12.3%) when exiting the oven. It is produced in Mem Martins since October 2012 (previously produced in the Amsterdam), where it is also produced, although in much smaller quantities, Ritz Cheese. Both varieties are sold in the UK.

To calculate the CPM values for Ritz Original, it was also considered the last 3 months of 2012, to start the analysis since the beginning of the production of Ritz at this plant.

In an analysis by category of complaint, it was concluded that 40% of the 937 complaints received (from January to December 2013) were in the category of appearance, 28% in texture and 22% in taste. In appearance, 87% of the complaints received were in the category of broken; in texture, 63% of the complaints received were in the category of underbaked; and, in taste, 27% were in the category of salty and 25% of old taste. The category of foreign material was also analyzed, not because of the number of complaints in this category but because of its severity. It was concluded that only 1% of the 937 complaints received were in this category and, within this, 25% were in the category of non-identified material, 19% of hair and 12% of fiber.

Similarly to what was done before, the frequency of the complaints for Ritz Original was also analyzed, concerning the date of production of the claimed products. Figure 2-4 shows the complaints over time, according to the different categories analyzed before.
As can be seen in the Figure 2-4, October 2012, the month when Ritz started being produced in Mem Martins, was the month with the highest CPM value, followed by January and February 2013. Analyzing Figure 2-4 B, it can be concluded that the complaints in October 2012, are mostly by underbaked cookies. However, in the following months there were no complaints in this subcategory (except January 2013).

Regarding the category of appearance – broken (Figure 2-4 A), it can be seen that the complaints in CPM are constant over time, with a slight tendency to decrease throughout the year. For lower CPM values, there were complaints in the category of taste for salty and old/stale taste. These complaints are always more subjective to analyze because they depend on the senses, which may vary from person to person. By comparing Figure 2-4 C and D, it can be concluded that the complaints in the subcategories of salty and old/stale rarely overlap in time. The months with the highest incidence of complaint on salty were November 2012 and January, March and April 2013 as the months with the highest incidence of complaint on old/stale taste were October 2012 and February of 2013. It can also be concluded that the incidence of complaints in October 2012 in old/stale taste overlap with the complaints for underbaked. This may be justified by the fact that underbaked cookies absorb moisture from the air while cooling after leaving the oven. This moisture, after some time, promotes reactions of lipid oxidation, accelerating the aging of the product, conferring an abnormal taste that could be in the origin of these complaints.

The Figure 2-4 E shows the distribution of complaints in the category of foreign material over time. This category is not worth treating subcategories separately because none of them stands out from the others. The months with the highest incidence of complaints by foreign material were February and October 2013, with 3 complaints (in absolute number) that never match in subcategory. In February, the amount of CUs produced was much lower than in October, presenting a higher CPM value.

Identified the focus of complaint to this cookie, they were compared with the plant non-compliance. It turns out that, despite the 937 complaints received by the end of December 2013, there were only 14 records of non-compliance. Of the 14 records, only 5 were related to finished product, i.e., only 5 could relate to the complaints received. Anyway, no record coincides with the focus of complaint identified. However, there is a record of non-compliance by incorporation of foreign material.

The results obtained through this comparison between non-compliance records and complaints were not anticipated. It would be expected that non-compliances would be detected upstream, avoiding consumer complaints. It could be argued that the biscuits break after leaving the plant, during transportation to the place where they are sold. The same cannot be claimed for the underbaked cookies. There is an implemented control to prevent underbaked cookies to leave the plant, analyzing its moisture when they leave the oven. However, there’s no record of this non-compliance in the 15 records analyzed. Therefore, it could be argued that these complaints are not founded, despite the high number of complaints.

3. Analysis of the major categories of complaint for Original Ritz

3.1. Materials and methods

3.1.1. Complaints for appearance – broken

To evaluate the complaints in this category, a study was performed on the percentage of biscuits cracked/broken inside a package of Ritz Original (breakage). Defective biscuits were divided into two categories: the biscuits with a defect which represented a loss of more than 25% were considered "broken", and biscuits with a minor defect, below this threshold were considered "top". Biscuits with more than one defect considered "top", are placed in the category "broken". Considering the specification limits defined by Mondelēz International, a package of biscuits, when leaving the plant, should not be more than 10% of "broken" and 10% "top". All analyzes conducted under this category took into account these specification limits.

Firstly, the breakage of Ritz was studied considering their production date, analyzing one of the two CUs stored in the plant, from October to December 2013 (from the lot OMM0434012 to OMM0435153).

After that, the breakage was evaluated in the different areas of the packaging section of the production line (Figure 3-1) in order to conclude if there was an area responsible for the high breakage values. Thus, three packages from each one of the two packaging machines and one cardboard box (with 12 CUs) from each one of the two cardboard box machines were collected and analyzed. Samples were taken between the shift 2 (8-16h) and 3 (16-24h), so that it could also be studied if the different shifts, with different operators, for example, had influence in the breakage values. 20 samples were collected, 1 per shift.

Finally, the breakage values were analyzed before and after the alteration of the critical step in breakage in the production line, verifying its effectiveness. For this purpose, samples were taken at the four points identified above, but now only three packages were analyzed for all the points (instead of the whole cardboard box). This time, 28 times were collected, 4 per shift.

The analysis of breakage, i.e., the percentage of "broken" and "top" biscuits per package was performed weighing the closed
package and later, opening it, classifying separating the biscuits in perfect, "broken" and "top" and weighing the two categories. The ratio between the weight of the "broken" and the closed package, is the "broken" fraction of the package. The same is true for the "top" fraction of the package. This technique was common in all breakage studies.

3.1.2. Complaints for taste – old/stale taste

To evaluate the complaints in this category, a study was performed, analyzing the several features of the product and the process that could justify an old/stale taste. As mentioned in the previous chapter, the Ritz family was produced at another plant, where coconut oil was sprayed in the biscuit when leaving the oven. When transferring the production of Ritz to Mem Martins plant, the coconut oil was changed to palm oil, and it is believed that this change in the process may be in the origin of some complaints concerning the taste of this biscuit.

Besides the change in the recipe, the peroxide index in palm oil was analyzed, to see if rancidity was behind the old/stale taste complaints. Thus, samples of oil were collected at three different points of the oil spray machine area: new oil, coming from the storage (point 1); recovered oil, after bathing the cookies (point 2); and mixed oil, from the oil tank below the machine (point 3). In these three points, samples were collected at three different production times. All this sampling was repeated on another day, doubling the number of samples per time point and per time, totaling 18 samples of oil to be analyzed. The analysis of the peroxide index in the palm oil was performed according to the normative P904:1987 [11], where the peroxide index of a oil is defined as the amount of active oxygen, expressed in milliequivalents (meq), per kilogram of oil. The procedure used to determine the peroxide index is the oxidation of potassium iodide, in an acetic acid medium, by active oxygen from known oil mass, and determination of the corresponding amount of iodine titrated with sodium thiosulfate solution in presence of starch as indicator.

After determination the peroxide index of the oil sprayed into the cookie when exiting the oven, the same analysis was performed for the fat extracted from the cookie. For that, cookies from a lot claimed in this category were analyzed (OMM0433353), among with cookies from an unclaimed lot, produced at the same time (OMM0432853) and, finally, with cookies from a most recently produced lot (OMM0440443). The analysis of the moisture content of the cookies was performed as indicated on the normative NP875:1994 [12].

3.1.3. Complaints for taste – salty taste

As said when introducing this cookies, in addition to the amount of salt in the dough, after formation and before entering the oven, it is applied a topping of salt in the surface of the cookies. However, there is growing concern about the excessive amounts of salt in some foods, since this is directly related to cardiovascular diseases.

To examine whether the biscuit was excessively salty, the results of an analysis of the chloride content of cookies is performed, collecting and analyzing a finished CU sporadically over time, as described on the normative NP1509:1977 [13], i.e., extracting chloride ions from the sample with boiling water and determining their concentration in a solution by titration with silver nitrate, using dilute potassium chromate solution as indicator in a process known as Mohr's method.

3.1.4. Complaints for foreign material

In order to analyze the risk of contamination by inclusion of foreign material in the production line, an analysis of all potential hazards in the areas surrounding it was performed. In addition, the situations identified as a potential hazard were classified in terms of severity and probability of occurrence (from 1 to 3). These two variables, when multiplied, represent the risk of inclusion of foreign material through that specific situation. The severity of the accidental inclusion of a foreign object in a package of cookies depends on its material, its size and its shape. In terms of materials, metal is the most dangerous; in terms of shape, the more pointy and sharp the object, the greater the hazard; and, in terms of size, the relationship between size and severity is not easy to establish because, obviously larger objects pose a greater danger to the consumer’s health but are also easier to detect. It must be noted that production lines are designed to minimize accidental inclusion of foreign material. However, for any eventuality, there are installed, along the production line, equipment (filters, metal detectors) that prevents the possibly contaminated product to leave the plant [14].

Besides this analysis, a more detailed analysis was carried out at the raw materials weighing room.

3.2. Results and discussion

3.2.1. Complaints for appearance – broken

From the analysis of the CUs stored in the plant, it was concluded that the values of breakage have been consistently high over time. It also could be concluded that the percentage of biscuits classified as "top" was above the percentage of "broken" in most of the packages analyzed, being often above the maximum limit defined in the specification (10%).

Figure 3-1 A and B represent the comparison between vertical packaging machines 1 and 2, on the percentage of biscuits classified as "broken" and "top", respectively.
In the evaluation of the breakage values in the different areas of the packaging section, it was concluded that, in the vertical packing machines, there were many values above the maximum allowable by the specification. For the “broken” category, in the 60 packages collected from the vertical packing machine 1, 6 proved to be non-compliant, while for vertical packing machine 2, only 1 had more than 10% of its weight classified as “broken”. Regarding the “top” category, there isn’t a big difference between the two vertical packing machines. For vertical packing machine 1, 23 packages revealed cookies classified as “top” over specification while, for the vertical packing machine 2, 27 revealed the same characteristic. For the two packing machines analyzed, the sample showed more than a third of non-compliance in this parameter, which somehow justifies the complaints in this category.

From the analysis of the breakage between the cardboard machines 1 and 2, it was concluded that, as before, the “top” category had more non-compliances. However, there was no big difference between the results obtain for each cardboard machine. The same could be concluded from the analysis between shifts of production.

Later, it was decided to replace the vertical packing machine 1 with another existing in the plant, which worked faster and with lower breakages values.

Figure 3-2 represents the average breakage values for each sampling point, before and after the changing of that machine.

Analyzing the Figure 3-2 A and B, it can be concluded that the level of breakage, after changing the vertical packing machine 1 with the “new” packing machine (known as vertical packing machine 3), decreased substantially. Compared with the packing machine 1, the average breakage values dropped from 4.8% for “broken” and from 12.3% for “top” to 1.6% and 5.7%, respectively. Regarding the packing machine 2, the breakage values remained the same, as expected, however with a slight decrease in the “top” category. The cardboard machines 1 and 2 had their breakage values reduced, which would be expected, since they are fed by a random mixture of packages from the two vertical packing machines. As had already been concluded, the cardboard machines don’t have a strong influence on breakage. The current characterization of breakage for the cardboard machine 1 is 2.8% for “broken” and 8.0% for “top” cookies inside a packages and, to the cardboard machine 2, it is 2.6% for “broken” and 8.0% for “top” cookies inside a package, all below the limit given by the specification of Mondelēz International.

3.2.2. Complaints for taste – old/stale taste

Table 3-1 presents the average peroxide index in the oil for the three different sampling points at three different instants.

<table>
<thead>
<tr>
<th>Time</th>
<th>Sample</th>
<th>Peroxide index (meq O₂/kg oil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9h</td>
<td>New oil</td>
<td>1.62</td>
</tr>
<tr>
<td></td>
<td>Recovered oil</td>
<td>1.40</td>
</tr>
<tr>
<td></td>
<td>Mixed oil</td>
<td>1.66</td>
</tr>
<tr>
<td>16h</td>
<td>New oil</td>
<td>1.34</td>
</tr>
<tr>
<td></td>
<td>Recovered oil</td>
<td>1.60</td>
</tr>
<tr>
<td></td>
<td>Mixed oil</td>
<td>1.34</td>
</tr>
<tr>
<td></td>
<td>New oil</td>
<td>1.39</td>
</tr>
<tr>
<td></td>
<td>Recovered oil</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>Mixed oil</td>
<td>1.20</td>
</tr>
</tbody>
</table>

From the Table 3-1, it can be concluded that there is no relation between the constant recirculation of the oil and the peroxide value, despite of the time. This can be justified by the fact that the oil used in the plant is enriched with chemical...
antioxidants. According to the decree no. 928/98 of 23 October, the peroxide values (expressed in meq O$_2$/kg) for fats, oils and refined virgin oils without antioxidants must be under 10, and for fats and refined oils with antioxidants must be under 5, to ensure that the designated product is free from rancid taste and smell. Thus, one cannot blame the peroxides in the oil used as coating for the old/stale taste claimed for these biscuits.

Table 3-2 presents the average peroxide index in the fat extracted from the cookies from three different sampling lots.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Peroxide index (meq O$_2$/kg fat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Claimed lots</td>
<td>1.93</td>
</tr>
<tr>
<td>Unclaimed lots</td>
<td>1.31</td>
</tr>
<tr>
<td>Recently produced lot</td>
<td>2.44</td>
</tr>
</tbody>
</table>

From the Table 3-2, it can be concluded that the peroxide index of the fat extracted from the cookies of the claimed lots is slightly higher than the peroxide index of the fat extracted from the cookies of the unclaimed lots, though produced at the same time. However, the lot corresponding to the cookies produced more recently has the highest peroxide index of all. This last result was not expected since the peroxides intensify over time, so it would be expected a lower peroxide index in the most recent cookies. However, all the values are still very low, taking into account the values presented before, in the decree no. 928/98.

Table 3-3 presents the moisture values obtained from the analysis of cookies from three claimed lots, from three unclaimed lots, produced at the same time, and from a recently produced lot, use as control.

<table>
<thead>
<tr>
<th>Moisture values (% w/w)</th>
<th>Claimed lots</th>
<th>Unclaimed lots</th>
<th>Recently produced lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>4.5</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>4.4</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td>4.5</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

From the Table 3-3, it appears the moistures values for cookies from the claimed lots were generally higher than those from the unclaimed lots, produced at the same time. The moisture obtained for the cookies most recently produced was lower than those produced before. This result suggests that the packaging of reclaimed cookies could have been formed with small defects, not detectable by visual inspection, not totally protecting the product from atmospheric moisture. These results can also suggest that those cookies were underbaked, absorbing moisture from the atmosphere after leaving the oven. According to the specification defined by Mondeléz International, the target moisture for Ritz Original after leaving the oven is 2.50%, with a tolerance of ± 0.70%. Considering this information, it can be concluded that the moisture from the cookies of the recently produced lot was also over the upper limit of specification (3.20%), which reinforces the need of improved control procedures.

3.2.3. Complaints for taste – salty taste

All data concerning this category was collected by the Quality Department team and provided for this study. Figure 3-3 shows the chloride content (in % w/w) of Ritz cookies over time. From its analysis it can be concluded that, except in the first months of production and in a period of transition between specification values, from July to October, the chloride content was generally within the specified values.

In October 2013, the target values concerning the chloride content for Ritz Original decreased from 1.4 - 2.2% to 0.7 - 1.5%, which resulted in changes in the certain parameters in the process like the salt deposition speed on the pieces of fresh dough.

To simplify the analysis of the chloride content in cookie samples, in January 2014, an electronic instrument was purchased (Mettler Toledo EasyPlus™). This device combines many technologies, monitoring of acid-base and redox reactions in order to make possible the different analysis in food, beverages and chemical industry. After some tests to validate the new analytical method, from February 2014 on, the analysis of the chloride content was performed using the new device.

3.2.4. Complaints for foreign material

Analyzing the document that assembles all 74 situations identified as potential hazards, it can be concluded the area with the highest number of risk situations is where the raw materials are weighted. Practically all unit operations present the risk of inclusion of screws or bolts. The severity attributed to this risk is of 3, being metallic objects, but 1 was the probability of occurrence assigned to this, because it is relatively unlikely to loosen a screw or a bolt, falling to the production line. Thus, the calculated risk for this situation is always 3. There was no situation identified with maximum risk, with index equal to 9. Among the situations identified with an index between 4 and 6, they were the possible inclusion of hard plastic throughout the containers used in the weighing of liquid materials, in which the severity index is of 3, because it is hard plastic and because there are already several containers in poor condition, assuming a value of 2 for the probability of occurrence. Another situation identified with the exact the same value is the inclusion of plastic fibers from the brush below the salt equipment. Plastic fibers are also hard plastic and the likelihood is, again, considered as 2, since these fibers are always in motion, due to the rotational movement of the mat under it. The improvement suggestions these two situations pass by, in the case of plastic boxes, acquire new and more robust, an regarding the brush, its use.
in this section of the production line is not that important for the risk it represents. Thus, it should be simply removed. The last situation with a risk index between 4 and 6 is the inclusion of metallic film (severity of 3) from the enzyme bags in the mixing area, where the probability of occurrence was considered of 2, because 2 packages are used per dough and, by opening them, small fragments of metal foil can be lost accidentally.

4. Final conclusions

In this study, there can be identified situations where the PDCA cycle was followed. The first example is the analysis of the complaints in the breakage category, where an opportunity for improvement was identified, the sampling was planned and carried out, the results were analyzed and, with these, action was taken on the source of the problem, replacing the vertical packaging machine 1. Another example is the analysis of the complaints in the category of old/stale taste. The peroxide values in the coating oil were analyzed, as a possible source for the complaint. The sampling was planned, carried out and the results led to the conclusion that the peroxide value of the oil was not high enough to cause a change in the cookies flavor, as they were always below 5 meq O₂/kg oil. It was then decided to analyze the peroxide values of the fat extracted from the cookies. Again, the sampling was planned, carried out and the results led, again, to the same conclusions. Following these, it was decided to analyze the cookies' moisture values, which led to the conclusion that old/stale taste was associated with cookies with higher moisture values.

The categorization of the complaints by the VOICE platform should be considered as a limitation of this study, since the consumer, when complaining, is not properly trained to clearly express the exact reason of his complaint. This way, the responsibility of this categorization belongs to the operator of VOICE, which has to listen to the consumer and translate what he has heard to information fit for statistical analysis.

For most complaints categories, there can be identified actions of improvement concerning the production process and the detection of non-conformities in the plant. With the intent to put an end to the breakage situation, during this study, it was found a machine very similar to the vertical packing machine 1, slightly tilted and specialized for delicate products. This tilting divides the product fall in two sections: a first section, in which the product falls freely from the weighing scale to the machine; and a second section, in which the product slides through the machine wall to the pre-formed bag. The decreased height leads to lower breakage values. If the replacing of the vertical packing machine 1 by another packing machine wouldn't have happened, this tilted machine could have represented a solution. However, even before this study, there were already been implemented some alterations in the vertical packing machines, installing a slide that hold the package in its fall. This, however, manifested itself insufficient to meet the objectives. To conclude, it must be noted that it would be of great interest to implement a visual control on the formed bags, so that there could be detection on product with higher breakage.

Regarding the complaints in the taste category, the only evidence that could have led to an old/stale taste would have been the high moisture of the cookies. However, there was an intervention in the temperature profiles in the oven, to prevent future problems with underbaked cookies. For the complaints in the salty taste category, it is believed that the problem was on the product specifications, which considered the chloride content above of what the customer considers allowable, even for a salty cracker. This assumption was proven when, with the reduction of the salt deposition in the cookies also came the reduction of the number of complaints in this category. It must be said that, in the end of the production line, the cookie is tasted, being approved if the organoleptic properties are within expectations. This control is effective to verify the salty taste and to verify if the cookies are properly baked, but it is not effective to control the old/stale taste, as this characteristic only develops over time. Therefore, the only thing that can be done is to make sure that the peroxides values remain consistently low and that the bags are properly sealed. In order to maintain the properties of the finished product over time, in August 2013, the bags of the Ritz family were changed from transparent plastic film for a new film, metallic and opaque, preventing the light to contact with the product inside the package, which is one of the promoting factors for oxidation reactions, as indicated above. However, the use of this opaque film represents a disadvantage in terms of process control, avoiding the possibility of visual detection of high breakage packages.

Finally, in the category of foreign materials, no situations of maximum risk were identified. From the 74 situations identified, there were only 3 classified as of average, which manifests the constant concern of the Quality team of the Mem Martins plant to maintain the safety of its products.

To conclude, it is important to note that there is no process without variability, and receiving complaints, due to this variability, is inevitable. The act of complaining and the tolerance that triggers the complaint have cultural influence, varying from country to country. Perhaps, Ritz family only has a high number of complaints because it is sold in the UK, where the consumers are known to be very demanding.

5. References