11.1 Introduction

Potatoes are the fourth most important vegetable crop in the world and the main utilization of processed potatoes includes table stock (31%), frozen French fries (30%), chips and shoestrings (12%), and dehydrated items (12%) (Miranda and Aguilera, 2006). Potatoes are grown in approximately 80% of all countries and worldwide production stands in excess of 300 million tons/year, a figure exceeded only by wheat, maize, and rice. As the eating habits of consumers have become more sophisticated, much attention has been given to the quality of fried and dehydrated food, which is greatly affected by process- and/or storage-induced changes. Processed potato products such as potato chips have been popular salty snacks for 150 years and their retail sales in the US are about $6 billion/year representing 33% of the total sales of this market (Clark, 2003; Garayo and Moreira, 2002).

Chemical composition of potato varies with cultivar, location of growth, agricultural practices, maturity at harvest, and subsequent storage history, among others. Potatoes are mainly made up of water (≈75% on average). Starch, comprising 65–80% of the dry matter content of the potato tuber, is calorically the most important nutritional component. The composition of potato starch is about 21% amylose, 75% amylopectin, 0.1% protein and 0.08% phosphorus. The content of reducing sugars is closely related to the final color and acrylamide formation of the fried potatoes. For example, a maximum of 1 g/kg reducing sugars has been suggested as a way to diminish significantly the formation of acrylamide after frying. On the other hand, selecting of cultivars to fry that contain low levels of asparagine (another acrylamide precursor) may result in low-acrylamide fried potatoes (Friedman, 2003). Finally, the two main factors that influence the sugar content of potatoes during post-harvest storage are variety and storage temperature. For frying, potatoes with high solids content (20–22%) are preferred, because they result in better texture, higher yields, and lower oil absorption in the finished product (Lesinska and Leszczynski, 1989).

Deep-fat frying is one of the oldest and most common unit operations used for cooking foods by immersing them in an edible oil or fat heated above the boiling point of water (Farkas et al.,
This complex unit operation involves significant microstructural changes; in fact, most of the desirable characteristics of fried foods are derived from the formation of a composite structure: a dry, porous, crispy and oily outer layer or crust, and a moist cooked interior or core, whose microstructures form during the process (Bouchon et al., 2001). The high temperatures (around 160 and 180°C) cause water evaporation, which is transferred from the food towards the surrounding oil, whereas oil is absorbed by the food replacing part of the released water. This process results in products with a unique flavor–texture combination (Mellema, 2003).

On the other hand, drying is a widely used method of fruit and vegetable preservation. Water is removed to a final concentration, which assures microbial stability of the product and minimizes chemical and physical changes (Lewicki and Jakubczyk, 2004). Nowadays, drying is regarded not only as a preservation process, but also as a method for increasing added value of foods (Ramos et al., 2003). Processing of plant raw materials causes irreversible changes in the tissues of fruit and vegetables. These changes are particularly visible after heat treatment (Lisińska and Golubowska, 2005). In this chapter, the most important issues related to unit operations used to process potatoes such as frying and dehydrating will be shown.

### 11.2 Fried Potato Products

Deep-fat frying is a complex unit operation involving high temperatures, significant microstructural changes both to the surface and the body of the chip, and simultaneous heat and mass transfer resulting in flows in opposite directions of water vapor (bubbles) and oil at the surface of the piece (Bouchon et al., 2003). In fact, most of the desirable characteristics of fried foods are derived from the formation of a composite structure: a dry, porous, crisp and oily outer layer or crust, and a moist cooked interior or core. The crust is the result of several alterations that mainly occur at the cellular and sub-cellular level, and are located in the outermost layers of the product. Deep-fat frying can be defined as well as the process of drying and cooking through contact with hot oil (Sahin et al., 1999). High heat transfer rates are largely responsible for the development of the desired sensorial properties in fried products (Hubbard and Farkas, 1999). Although data are still inconclusive, it appears that longer times and lower frying temperatures lead to higher final oil contents in fried potato products.

Potato chips are very thin pieces (1.27–1.78 mm thick) of sliced raw potatoes that are fried to a final oil and moisture contents of ~35% and 1.7%, respectively (Moreira et al., 1999). For potato chip processing, raw potatoes are washed, peeled, and cut in slices whose shape and width vary according to consumer preferences. Then, the cut slices are washed to remove the starch excess and dried to eliminate surface moisture. Some processing plants use blanching to improve the final product color. Then the slices are fried until reaching a final moisture content of almost 1.8% and the oil excess over the fried chips is removed and salt in the proper quantity is added. Finally, potato chips are cooled and classified according to their size before being packaged (Bouchon, 2002).
final oil content of 33–38% in total basis (Moreira et al., 1999). Potato chips contain a significant amount of fat, reaching in many cases ∼1/3 of the total food product by weight (Mellema, 2003). This ensures a high level of satiety, but can also pose a risk. Especially over the last decade the desirability of the reducing fat content of deep fried products has been recognized.

On the other hand, yearly production of French fries in the US is higher than 17.4 billions of pounds and constitutes almost 44% of the total processed potato. French fries represent a composite structure formed by two regions: (i) an external dehydrated and crispy region where oil is located; and (ii) a humid and cooked core region free of oil. The external crust is very similar to the structure of a fried potato slice or potato chip (Bouchon, 2002; Pedreschi et al., 2001; Pedreschi and Aguilera, 2002). For French fry processing, firstly the raw potato strips are blanched in hot water and dried with hot air until reaching a moisture content of around 60% (total basis). Then, the dried potato strips are fried in hot oil (160–190°C), cooled, frozen, and finally packaged (Bunger et al., 2003). The final preparation of the par-fried frozen potatoes could be accomplished by a final frying or baking. The final oil and moisture content of French fries are of almost 15% and 38%, respectively (Aguilera and Gloria, 2000; Saguy and Dana, 2003).

Factors which affect heat and mass transfer during frying are the thermal and physical–chemical properties of the food and oil, the food geometry, and the oil temperature. Many variables are involved in the traditional frying process of potatoes:

1. Variables dependent of the process: (a) temperature and time of frying; (b) frying method: batch or continuous; (c) potato variety.
2. Variables dependent of the oil type: (a) oil composition; (b) additives.
3. Variables dependent of the raw material: (a) surface/volume relations; (b) fat content, (c) moisture content. The interaction of these variables determines the characteristics of the fried product (Navas, 2005).

In deep-fat-fried potato products, both health and sensory aspects should be addressed to meet consumer demand. Consumer trends are moving toward healthier foods and low-fat products, creating the necessity of developing technologies to reduce the amount of oil in end-fried products (Bouchon et al., 2003). In order to obtain low-fat fried potatoes, it is useful to understand the mechanisms involved during the frying process, so that oil migration into the structure can be minimized. Numerous studies have shown that most of the oil is confined to the surface region of the fried potatoes (Bouchon and Aguilera, 2001; Bouchon et al., 2001; Pedreschi et al., 1999), and there is evidence that it is mostly absorbed after frying during the cooling period (Aguilera and Gloria-Hernandez, 2000; Bouchon et al., 2003; Ufheil and Escher, 1996).

Bouchon et al. (2003) explained that three different oil fractions can be identified as a consequence of the different absorption mechanisms in fried potato cylinders, that is: (i) structural
Figure 11.1: Oil uptake versus moisture content during frying of potato slices. Lines connect experimental data corresponding to the same frying temperature. □ 120°C, ○ 150°C, Δ 180°C (reprinted with permission from Lebensmittel-Wissenschaft und-Technologie, 2006, 39, 285–291).

oil (STO), which represents the oil absorbed during frying; (ii) penetrated surface oil (PSO), which represents the oil suctioned into the food during cooling after removal from the fryer; and (iii) surface oil (SO), which is the oil that remains on the surface (Figure 11.1). These authors showed that a small amount of oil penetrates during frying because most of the oil was picked up at the end of the process, suggesting that oil uptake and water removal are not synchronous phenomena. These findings have been confirmed by Pedreschi et al. (2008) and Durán et al. (2007).

Oil content versus moisture content in dry basis for control slices fried at 120, 150, and 180°C is shown in Figure 11.2. There is a clear effect of the frying temperature on oil uptake at moisture contents ≤ 1 g water/g dry solid; the higher the frying temperature the lower the oil content – average values of 0.39, 0.35, and 0.30 g/g dry basis for 120, 150 and 180°C, respectively. Figure 11.3 shows kinetics of total oil (TO) uptake and their different fractions (PSO, STO,

Figure 11.2: Diagram showing the three locations of oil in the crust of a fried potato piece according to Bouchon et al. (2003) (used by permission of the Journal of Food Science, Institute of Food Technologists).
Figure 11.3: Kinetics of oil uptake fractions and total oil in potato slices during frying at: (a) 120°C; (b) 150°C; (c) 180°C. TO: total oil; PSO: penetrated surface oil; SO: surface oil; STO: structural oil (reprinted with permission from J. Food Eng., 2008, 87, 200–212).
and SO) in the structure of potato chips fried at 120, 150, and 180°C. At very short frying times (between 1 and 4 minutes) almost 75% of the total oil content of final control potato chips (chips with ~ 1.8% of moisture content in total basis) is absorbed. After that time interval, the TO content remained almost constant until the moisture content (total basis) reached 1.8%. As the frying temperature decreased, the frying time required to reach that final moisture content and the TO increased. Similar results have been found in pre-treated potato chips, fried potato cylinders, and tortilla chips (Bouchon et al., 2003; Durán et al., 2007; Moreira et al., 1997).

This result suggests that the total oil in potato chips is absorbed almost in the initial stage of frying once the potato slices are placed inside the hot oil. Almost 75% of the total oil content of the fried product (chips with ~ 1.8% moisture content) was attained soon after immersion in the frying oil (between 1 and 6 minutes).

The distribution of oil fractions during frying of potato at three oil temperatures slices is shown in Figure 11.4. PSO constituted the highest fraction of TO during frying of the control; the higher the frying temperature, the higher the percentage of PSO based on the TO content (e.g. 78, 85, and 89% for 120, 150, and 180°C respectively). When the slices were removed from the fryer, a higher temperature difference develops between the surface and the interior, which, in turn, generates a higher negative pressure in the pore space leading to more oil penetration into their microstructure during cooling. This fact confirms that the oil absorption is principally a surface phenomenon (Aguilera and Gloria-Hernández, 2000; Bouchon et al., 2003; Durán et al., 2007; Ufheil and Escher, 1996). STO is the second important fraction in the TO content during frying of both control and blanched slices (Figure 11.4). As the frying temperature increases, STO penetration drops, since the higher internal pressures developed at higher temperatures make it more difficult for the frying oil to penetrate the potato structure whilst inside the fryer. The percentage of STO ranged between 7–18% for potato slices. This confirms that a small amount of oil penetrates during frying, because most of the oil is picked up at the end of the process, suggesting that oil uptake and water removal are not synchronous.
Figure 11.5: SEM images of the surface of control (a) and petroleum ether washed control for one second after frying (b) potato chips (moisture content ∼ 1.8%, total basis) fried at: (1) 120°C; (2) 150°C; (3) 180°C (reprinted with permission from J. Food Eng., 2008, 87, 200–212).

phenomena. The SO fraction was the lowest constituent of TO content (approximately 4% of the total oil content) and remained almost independent of the frying temperature (Pedreschi et al., 2008).

Scanning electron microscopy (SEM) is a powerful tool used to study the surface topography of potato chips. Figure 11.5 shows that potato chips lose a considerable quantity of surface oil after they are washed in petroleum ether, which allows clear observation of the cellular microstructure of the surface (Figures 11.5b1, 11.5b2 and 11.5b3) (Pedreschi et al., 2008).

The other important quality parameters in fried potatoes are: moisture content, texture (crispness and shrinkage), color and, of course, flavor. Researchers have reported different means to improve quality in fried products. The blanching step previous to frying improves the color and texture (Fan et al., 2005; Shyu and Hwang, 2001). Shyu and Hwang (2001) immersed apple slices in fructose solution prior to frying, which resulted in a reduction of absorbed oil after frying. Pre-drying of potatoes is a common way to reduce fat uptake in fried potatoes (Krokida, et al., 2001; Moyano et al., 2002). Besides, properties of the surface of the potatoes are highly relevant for fat uptake, so the application of a coating is a promising route to reduce oil content (Mellema, 2003).
Finally, in order to improve the quality of potato chips, vacuum frying may be an option for production of fruits and vegetables with low oil content and the desired texture and flavor characteristics. It is defined as the frying process that is carried out under pressures well below atmospheric levels (Garayo & Moreira, 2002). Due to the pressure lowering, the boiling points both of the oil and the moisture in the foods are lowered. Vacuum frying has some advantages that include: (1) reduction of the oil content in the fried product; (2) preservation of the natural color and flavors of the product due to the low temperature and oxygen content during the process; and (3) reduction of adverse effects on oil quality. Granda et al. (2004) concluded that vacuum frying can also reduce the acrylamide content in potato chips.

In April 2002, Swedish researchers shocked the food safety world when they presented preliminary findings of acrylamide in some fried and baked foods, most notably potato chips and French fries, at levels of 30–2300 μg/kg. Reports of the presence of acrylamide in a range of fried and oven-cooked foods have caused worldwide concern because this compound has been classified as probably carcinogenic in humans with significant toxicological effects, namely neurotoxic and mutagenic (Rosen and Hellénäs, 2002; Tareke et al., 2002). French fries and potato crisps exhibit relatively high values of acrylamide 424 μg/kg and 1739 μg/kg, respectively.

It has been stated that acrylamide is generated during a side reaction of the Maillard reaction. Crucial participants in this Maillard reaction in fried potatoes are an amino acid (asparagine) and reducing sugars (fructose and glucose) (Mottram and Wedzicha, 2002). Asparagine provides the backbone of the acrylamide molecule, while reducing sugars are essential co-reactants in the formation of the N-glycoside intermediates, which lead to the formation of acrylamide. Fried products, especially French fries and crisps, belong to the food category with probably the highest concentration of acrylamide recorded so far. The reason for this strong susceptibility to acrylamide formation is the abundance of free asparagine present in potato (Zyzak et al., 2003). Besides, fried potato color is the result of the Maillard reaction as well, that depends on the superficial reducing sugar content, and the temperature and frying period (Marquez and Añon, 1986). Consequently, for frying temperatures between 120 and 180°C, a linear correlation was found between acrylamide content and color not only in potato chips but also in French fries (Pedreschi et al., 2005, 2007). Figure 11.6 shows that the color difference parameter (ΔE) presented good correlation with the acrylamide content of the fried potato strips previously treated in the different ways. As the frying temperature increases from 150 to 190°C, the resultant chips get more red and darker as a result of non-enzymatic browning reactions that are highly dependent on oil temperature and frying time. Blanching reduces the ΔE values of French fries, probably due to the leaching out of reducing sugars previous to frying inhibiting in this way non-enzymatic browning reactions and leading to lighter and less red French fries (Pedreschi et al., 2004, 2006, 2007).
Acrylamide appears to form as a result of a reaction between specific amino acids, including asparagine, and sugars found in foods reaching high temperatures during cooking processes. The process is known as the Maillard reaction and occurs at temperatures above 100°C. Variation in suitability of potato tubers for processing is not influenced only by cultivar and storage conditions, but also by differences in normal cultural practice and growing conditions. A low amount of reducing sugars in the tuber is necessary to prevent the non-enzymatic Maillard reaction between sugars and free amino acids during frying. The Maillard reaction is responsible for the development of undesirable dark-colored compounds, melanoidins, with a bitter taste. On the other hand, it is essential for its contribution to the color and flavor of fried potatoes. Potato variety, composition, and field site had a noticeable influence upon acrylamide formation (Haase et al., 2003).

Recently, research has focused on possible mechanisms of acrylamide formation in foods in order to develop strategies to minimize its formation. Some international research groups have separately confirmed a major Maillard reaction pathway for acrylamide formation (Mottram and Wedzicha, 2002; Stadler et al., 2002; Weißhaar and Gutsche, 2002). Significant amounts of acrylamide are formed by the high-temperature reaction of glucose and the common amino acid asparagine (Coughlin, 2003). Since potato tubers contain a high amount of asparagine, it is now thought that this Maillard reaction is most likely responsible for the majority of the acrylamide found in potato chips and French fries. The potential for acrylamide formation is strongly related to the sugar content such as glucose and fructose (Biedermann et al., 2002; Pedreschi et al., 2006). For instance, some authors reported that the reduction of the sugar content by blanching or soaking could decrease acrylamide concentration by about 60% in potato chips (Haase et al., 2003; Pedreschi et al., 2004). Potato processing conditions (pre-treatments, temperatures, and
times) had a noticeable influence upon acrylamide formation. Asparagine is the free amino acid present in the highest amount in potatoes (93.9 mg/100g) (Martin and Ames, 2001). Asparagine content in potatoes depends on factors like variety, location, fertilization, storage, and processing (Davis, 1997; Hippe, 1998).

Blanching as pre-treatment has a great influence in diminishing acrylamide formation in potato pieces after frying (Pedreschi et al., 2004, 2007). Not only glucose but also asparagine content (Figures 11.7a and 11.7b) decreased drastically as the temperature and time of blanching increased leading to French fries with less acrylamide after frying. Acrylamide formation increased significantly in blanched samples when the frying temperature was increased.

Figure 11.7: (a) Glucose content of potato strips blanched in hot water at different temperature–time combinations before frying. (b) Asparagine content of potato strips blanched in hot water at different temperature–time combinations before frying. First numbers inside parenthesis indicate the blanching temperature (°C); second numbers indicate the blanching time (min). Control corresponds to unblanched potato strips (reprinted with permission from J. Food Eng., 2007, 19, 1287–1294).
(Figure 11.8). For instance, acrylamide contents were 287, 1338, and 2128 µg/kg after frying at 150, 170, and 190°C, respectively, in the case of potato slices blanched at 70°C for 10 min.

### 11.2.1 Blanching

Long-time blanching treatments such as that of 50°C for 80 min and 70°C for 45 min resulted in the lowest levels of acrylamide formation (342 and 538 µg/kg as average values for the three frying temperatures tested). These two blanching treatments after frying at 190°C, lead to the lowest acrylamide contents (564 and 883 µg/kg, respectively).

Currently, a substantial body of research has been carried out worldwide to build a greater understanding of acrylamide, how it is formed in foods, what the risks are for consumers, and how to reduce occurrence levels. Although many possible ways to reduced acrylamide content have been confirmed, the corresponding effects in sensory attributes in most of the reduction studies in fried potatoes have not been clearly reported yet (Zhang and Zhang, 2007).

### Dehydrated Potato Products

Drying is a widely used method of fruit and vegetable preservation. Water is removed to a final concentration, which assures microbial stability of the product and minimizes chemical and physical changes (Lewicki and Jakubczyk, 2004). Nowadays, drying is regarded not only as a preservation process, but also as a method for increasing added value of foods (Ramos
et al., 2003). Processing of plant raw materials causes irreversible changes in the tissues of fruit and vegetables. These changes are particularly visible after heat treatment (Lisińska and Golubowska, 2005).

Conventional air-drying is the most frequently used dehydration operation in the food industry (Krokida et al., 2003). Potato drying kinetics is greatly affected by air temperature, relative humidity, air velocity, and material size (Krokida et al., 2003; Mulet et al., 1989). Drying causes notorious physical and structural modifications of potato tissue. The most pronounced macroscopic modification is the shrinkage and deformation of food pieces undergoing drying. Transient thermal and moisture gradients develop tensional and compressional stresses. Stresses cause tissue breakage and fracturing during drying (Lewicki and Pawlak, 2005). Wang and Brennan (1995) showed that surface layers of potato slabs dried by air convection are severely damaged at short times, while the inner structure appears apparently intact. Further drying induces formation of cracks, the inner tissue is pulled apart and numerous holes are produced (Lewicki and Pawlak, 2005; Ramos et al., 2003). Loss of water and segregation of components occurring during drying, could cause rigidity, damage and disruption of cell walls, and even collapse of cellular tissue. These changes are associated with volume reduction of the product. Fast drying leads to cracking, resulting in final rigid products with more volume and a surface crust; slow drying rates result in uniform and denser products (Brennan, 1994).

Texture has been recognized as one of the most important quality attributes in dried potatoes which contribute to the consumer acceptance. Texture of potatoes is affected by drying processes and it is strongly associated with composition and structure of cell walls (Ramos et al., 2003). As previously stated, water loss is accompanied by loss of internal pressure; cellular tissue shrinks and becomes soft. This pressure is known as turgor pressure and plays an important role in the rheological and textural properties of the potato tissue.

Puncture and compression tests have been extensively used to measure the textural and viscoelastic properties of dried foods (Nisha et al., 2006; Ramos et al., 2003). The puncture test records the force required to push a probe into a food and it can be measured by the initial slope and the maximum breaking force extracted from the force–distance curve. Troncoso and Troncoso and Pedreschi (2007) studied the kinetics of textural changes during convection drying at different air temperatures (50, 60, 70, and 80°C) of potato slices by using four mathematical models which linked the dimensionless textural parameter obtained by a puncture test, maximum force $F^*_{\text{MAX}}$ with drying time. $F^*_{\text{MAX}}$ allows the study of global textural changes in potato tissue not only during the softening but also during the hardening stage (Krokida et al., 2000; Ramos et al., 2003). This parameter reflects physical and structural modifications of potato during drying which are closely linked to the turgor pressure of the tissue and the rigidity of cell walls (Ramos et al., 2003). Regardless of the different drying temperatures, the trend of $F^*_{\text{MAX}}$ with drying time was almost the same, showing a progressive and significant decrease
in its value as the exposure time increased especially at higher temperatures. The drying of potato slices originates the softening of the tissue. For high drying temperatures, the initial velocity of reaction of the softening process is fast showing a clearly pronounced negative slope (Figure 11.9). Then, the reaction velocity diminishes. Change in $F^{*}_{\text{MAX}}$ with moisture content during drying at different air temperatures is shown in Figure 11.10. $F_{\text{MAX}}$ in potato disks decreases with moisture content and it is affected significantly by the drying temperature ($P > 0.05$). On the other hand, Figure 11.10 shows that for moisture contents lower than $\sim 1.1 \text{ g/g dry solid}$, $F_{\text{MAX}}$ increases principally due to the low drying temperatures leading to irreversible changes in the product microstructure which results in the disruption of lamella media and increasing of cristalinity (Krokida et al., 2000).
Wang and Brennan (1995) modeled transport phenomena during potato drying. They use a mathematical model which considers simultaneous heat and moisture transfer permitting moisture and temperature distributions to be predicted during air drying of potato slices. This model took into account the effect of the moisture–solid interaction at the drying surface by means of sorption isotherms of food. Non-constant physical and thermal properties were also incorporated in the model. Experimental data and model calculations showed good agreement. On the other hand, Mayor and Sereno (2004) modeled the shrinkage of potatoes and other vegetables during convective drying using either empirical or fundamental models in order to give a physical description of the shrinkage mechanism and behavior during drying. Empirical models were obtained from regression analysis of potato shrinkage data and fundamental models were based on a physical interpretation of the structure of food materials. Average relative deviations between experimental and predicted values of shrinkage in potato and other vegetables were found in more cases less than 10%.

Krokida et al. (2001a) studied the effect of the method of drying on the color of dehydrated products. Five different methods of drying were used: conventional, vacuum, microwave, freeze, and osmotic drying. Changes in color parameters $a^*$ (redness) and yellowness ($b^*$) followed a first-order kinetic model. Freeze drying was the method that best preserved the color of potatoes, avoiding extensive darkening caused by the other methods of drying. On the other hand, Severini et al. (2005) studied drying in potato cubes pre-treated with a blanching. Blanching was alternatively performed in hot water, hot sugar–saline solution, by microwaves in distilled water, or by microwaves in saline solution. Drying was alternatively carried out in an air cabinet, a microwave oven, or a belt drier. In terms of process speed, color retention, and water absorption capacity, the best results were obtained combining microwaving blanching with dehydration on the belt dryer.

During air drying, potatoes undergo several simultaneous physical and structural modifications which are undesirable (McMinn and Magee, 1997). Thus, potato cylinders when dried in a convective dryer showed that moisture removal was accompanied by almost negligible internal porosity (< 10%), with air temperature representing the principal controlling factor. The dried potato cylinders suffered significant volumetric shrinkage which displayed a linear correlation with moisture content and air temperature. Also, Wang and Brennan (1995) studied structural changes of potatoes during drying with light microscopy. They observed that the degree of shrinkage of potato during low-temperature drying is greater than at high-temperature drying. Shrinkage also affects the physical properties of materials, such as the density and porosity. In the early stage of drying the density increased as the moisture content decreased, reaching a peak and then decreased with further decrease in moisture content. Total porosity increased steadily as moisture content decreased in the early stages of drying and then sharply toward the end of drying. The percentage changes in thickness, length, and width of the potato samples during drying increased linearly with decreasing moisture content.
Air drying could be used as a pre-treatment in frying operations and some authors have reported that they could reduce oil absorption in potato chips and increase texture in potato chips significantly (Pedreschi and Moyano, 2005b). Also, drying at high temperatures could cause the case-hardening phenomenon which consists of a surface hardening leading to a diffusion diminishing since there is an increasing in the resistance to water loss in potato pieces (Moyano and Berna, 2002). Leeratanarak et al. (2006) found that blanched potato slices dried faster than that corresponding to unblanched or raw potato slices. These authors concluded that the softening of the potato tissue during blanching reduces the case-hardening phenomenon after drying. Pedreschi and Moyano (2004) studied the effect in fried potato slices of blanching in hot water at 85°C for 3.5 min plus a drying treatment at 60°C until the potato pieces reached a moisture content of approximately 60%. Final potato chips blanched and pre-dried presented 24% less oil uptake than final blanched chips without pre-drying.

Potato could be dried to obtain potato flakes which are formed by potato starch granules. Potato starch granules are ellipsoidal, with a typical dimension of between 10 and 100 μm. They contain approximately 23% in wet basis of amylose and have amylopectin with β-type crystallinity. The granules are naturally low in lipids, but high in phosphates (Cheyne et al., 2005). Cooking processes are essential to allow starch to be metabolized by humans. They involve the action of heat, moisture and often mechanical action, and are a subset of actions termed starch conversion (Mitchell et al., 1997). There are some patented processes for making dehydrated potato products from potato flakes so that they can be sulfite-free by mixing the potato flakes with a sufficient amount of water to increase their moisture content to a predetermined level, lowering the temperature of the moistened potato flakes to a temperature and for a period of time sufficient for retrogradation of free soluble starch contained in the potato flakes, reducing the size of the potato flakes in a manner to minimize breakage of potato cell walls, and drying the resulting potato product. The dehydrated potato product can be reconstituted without using a boiling liquid to make a dough for French fries, chips, or to make a mashed potato product.

The process of converting potatoes into potato flakes involves many stages. Producing good-quality potato flakes is the result of controlling the operating parameters of all the equipment involved in the production process. Perfect process control and high-quality material and ingredients will assure excellent quality of the finished product. Yield ratio of ~ 6.7:1 and rehydration ratio of potato flakes to potato mash is 1:5. Potato flakes can be easily reconstituted with cold water, which led to its widespread use as an ingredient. This product has very good demand and wide application in industries, restaurants, fast-food joints, catering services, feeding programs, etc. Bouchon and Pyle (2004) use low-leach potato flake as the major ingredient in formulating restructured potato chips, since it is frequently used in the manufacturing of pellets or die-cut sheet snacks due to its high stickiness. In addition, it is a desirable ingredient because of the expanded texture and rapid palate clearance that it confers on finished products, mainly because the starch in potato flake is fully gelatinized (Bouchon, 2002).
11.4 Conclusions

Potato is one of the most important processed vegetables. Frying and dehydration are important unit operations used commonly by industry to process potatoes. Oil uptake and acrylamide content are major issues in fried potatoes related to the health and safety of consumers. Oil uptake in fried potatoes diminishes as the frying temperature increases. Most of the oil is absorbed when the fried potato pieces are removed from the fryer and penetrate into the microstructure during the cooling process. Acrylamide is a toxic compound (carcinogenic in animals), which is formed during frying mostly by the Maillard reaction mechanism in which asparagine reacts with reducing sugars such as glucose and fructose. Several methods to mitigate acrylamide formation have been studied such as blanching, soaking, acid addition, amino acid addition, etc. Since the flavor and taste of fried potatoes depend on the Maillard reaction, the major challenge is to produce fried potatoes with low acrylamide content without affecting their traditional flavor, taste, and other sensorial attributes. Drying of potato produces strong structural changes in the microstructure making crucial physical properties such as porosity, volume, thickness change abruptly with moisture loss affecting negatively the aspect of the final product.

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References


**Further reading**

