UNIVERSIDADE DE FEDERAL DA GRANDE DOURADOS
FACULDADE DE ENGENHARIA

INFLUÊNCIA DE COBERTURAS COMESTÍVEIS NA ABSORÇÃO DE ÓLEO E FORMAÇÃO DE ACRILAMIDA EM BATATA (*Solanum tuberosum*) FRITA

FRANCIELLI BRONDANI DA SILVA

DISSERTAÇÃO DE MESTRADO EM CIÊNCIA E TECNOLOGIA DE ALIMENTOS

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ATA DA **DEFESA** DE MESTRADO APRESENTADA PELA ALUNA **FRANCIELLI BRONDANI DA SILVA**, DO PROGRAMA DE PÓS-GRADUAÇÃO *STRICTO SENSU* EM CIÊNCIA E TECNOLOGIA DE ALIMENTOS, ÁREA DE CONCENTRAÇÃO "CIÊNCIA E TECNOLOGIA DE ALIMENTOS".

Aos vinte e sete dias do mês de junho do ano de dois mil e dezenove, às 13:30hs, em sessão pública, realizou-se, na sala de reuniões da faen da Universidade Federal da Grande Dourados, a defesa de mestrado intitulada "Influência de coberturas comestíveis na absorção de óleo e formação de acrilamida em batata (*solanum tuberosum*) frita", apresentada pela mestranda, Francieli Brondani da Silva, do programa de pós-graduação em Ciência e Tecnologia de Alimentos, à banca examinadora constituída pelos professores Dr.ª Silvia Maria Martelli, presidente/orientadora, Drª Cristina Tostes Filgueiras - membro titular, Dr. Eduardo José de Arruda - membro titular. Iniciados os trabalhos, a presidência deu a conhecer a candidata e aos integrantes da Banca as normas a serem observadas na apresentação da Dissertação. Após a candidata ter apresentado a sua Dissertação, os componentes da Banca Examinadora fizeram suas arguições, que foram intercaladas pela defesa do candidato. Terminadas as arguições, a Banca Examinadora, em sessão secreta, passou aos trabalhos de julgamento, tendo sido o candidato considerado ___APROVADO___, fazendo *jus* ao título de **MESTRE EM CIÊNCIA E TECNOLOGIA DE ALIMENTOS**. Nada mais havendo a tratar, lavrou-se a presente ata, que vai assinada pelos membros da Banca Examinadora.

Dourados, 27 de junho de 2019.

Prof.ª Drª Silvia Maria Martelli __Silvia Maria Martelli__ Presidente da Banca

Prof.ª Drª Cristina Tostes Filgueiras __Cristina Tostes Filgueiras__ Membro Titular

Prof. Dr Eduardo José de Arruda ____________________ Membro Titular

ATA HOMOLOGADA EM : _____/_____/_______, PELA PRÓ REITORIA DE ENSINO DE PÓS GRADUAÇÃO E PESQUISA/UFGD.

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RESUMO

A batata (*Solanum tuberosum*) ocupa a terceira cultura alimentar mundial, no Brasil, o consumo anual é de cerca de 14kg por habitante. Devido ao Brasil ser um dos gigantes emergentes econômicos, o mercado consumidor está mudando, é um país em expansão para lanches acompanhados com batatas processadas. O desenvolvimento de doenças crônicas não transmissíveis está relacionado a vários fatores: atividade física inadequada, ingestão excessiva de calorias e gordura, ingestão inadequada de vitaminas e minerais, consumo excessivo de álcool, genética, entre outros. O aumento no consumo de frituras é preocupante, tornando-se necessárias medidas alternativas que visem à menor absorção de óleos e gorduras em frituras. Sabe-se que alguns revestimentos comestíveis reduzem a absorção de óleo durante o processo de fritura (ex.: revestimentos à base de hidroxipropilmetilcelulose e soro de leite; goma de guar; carboximetilcelulose e pectina; semente de manjericão hidrocolóide (BSG) e salep; proteína de soro e pectina na presença de transglutaminase, metilcelulose). Conforme o tempo *x* temperatura de fritura e do óleo utilizado, reações químicas e enzimáticas ocorrem no óleo e no alimento, resultando em oxidação do óleo e produção de subprodutos tóxicos a saúde humana, como a acrilamida. Tecnologias têm sido estudadas com o intuito de mitigar a formação destes compostos nos alimentos. Desta forma, este trabalho teve como objetivo estudar a influência do uso de coberturas comestíveis a base de quitosana e amido de batata na absorção de óleo e formação de compostos tóxicos em batatas submetidas ao processo de fritura por imersão, a estabilidade oxidativa do óleo nos cilos de fritura, além do estudo da cinética de secagem, em 50, 60 e 70^{o}C, de batatas cobertas.

Palavras-chave: Batata inglesa, coberturas comestíveis, óleo de soja, estabilidade oxidativa, composto tóxico.

ABSTRACT

The potato (Solanum tuberosum) occupies the third food culture the world, in Brazil, the annual consumption is about 14kg per inhabitant. Because Brazil is one of the emerging economic giants, the consumer market is changing, it is a booming country for snacks accompanied with processed potatoes. The development of chronic noncommunicable diseases is related to several factors: inadequate physical activity, excessive intake of calories and fat, inadequate intake of vitamins and minerals, excessive alcohol consumption, genetics, among others. The increase in the consumption of fried food is worrisome, making necessary alternative measures that aim at the lower absorption of fats and oils in frying. It is known that some edible coatings reduce the absorption of oil during the frying process (eg, hydroxypropylmethylcellulose and whey based coatings, guar gum, carboxymethylcellulose and pectin, hydrocolloid basil (BSG) seed and salep; of serum and pectin in the presence of transglutaminase, methylcellulose). According to the time *x* frying temperature and the oil used, chemical and enzymatic reactions occur in the oil and in the food, resulting in oil oxidation and production of human health toxic byproducts, such as acrylamide. Technologies have been studied in order to mitigate the formation of these compounds. The objective of this work was to study the influence of the use of edible chitosan and starch based coatings on the absorption of oil and formation of toxic compounds in potatoes submitted to the frying process by immersion, in addition to the study of drying kinetics, 50, 60 and 70^{o}C, of potatoes covered.

Key words: English potatoes, edible coatings, soybean oil, oxidative stability, toxic compouds.

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INTRODUÇÃO

As transformações do estilo de vida e hábitos alimentares da população mundial devido a maior inserção no mercado de trabalho (GARCIA, 2003) colaboram com escolhas alimentares de rápido preparo, que por sua vez podem ter alta composição de gorduras. Nas últimas décadas, vem ocorrendo uma transição nutricional no Brasil, passando a população de um estado de desnutrição para o de aumento do sobrepeso e obesidade em todas as faixas etárias e grupos sociais (IBGE, 2010).

Existem vários estudos que investigam o consumo de alimentos com alto teor de gordura e sua relação com doenças crônicas não transmissíveis (FOX; KEYEYIAN, 2000; CEMBRANEL et al., 2017; MESSIAS et al., 2016; CORREIA, 2016; RUNNING; MATTES, 2016). A correlação entre o consumo abusivo de óleos vegetais e o desenvolvimento de doenças crônicas não transmissíveis está relacionada a vários fatores, como atividade física inadequada, ingestão excessiva de calorias e gordura, ingestão inadequada de vitaminas e minerais, genética, entre outros (BRASIL, 2014; MAHAN et al., 2012).

Dentre os alimentos práticos e rápidos, encontram-se os fast foods, que na sua maioria ofertam batatas fritas. Batatas são usadas para vários fins culinários, podendo ser cozidas, assadas ou fritas e usadas em uma variedade impressionante de receitas: purê de batatas, panquecas de batata, batatas fritas, batatas assadas, sopa de batata, salada de batata e batata gratinada (CIP, 2018). É provável que menos de 50% das batatas cultivadas em todo o mundo sejam consumidas frescas, o restante é processada em alimentos e ingredientes alimentícios de batata (CIP, 2018; USDA, 2016).

Dentre as preparações culinárias das batatas, destaca-se a fritura. A fritura por imersão é um método eficiente pela sua rapidez, sendo as principais características desse processo, a alta temperatura e a rápida transferência de calor (SANIBAL; MANCINI-FILHO, 2002). A fritura é um processo de preparação rápida de alimentos, confere aos produtos fritos características únicas de odor e sabor (ANS; MATTOS; JORGE, 1999) e contribui para o aumento do consumo de óleos e gorduras, pois melhora a palatabilidade, gerando alimentos sensitivos agradáveis (DEL RÉ; JORGE, 2006). Os óleos vegetais desempenham um papel importante na indústria de alimentos, uma vez que são capazes de melhorar as características sensoriais de alimentos como sabor, odor e textura (FOX; KEYEYIAN, 2000).

No processo, a temperatura de fritura o óleo interage com o ar, água e componentes dos alimentos que estão sendo fritos gerando compostos responsáveis por odores desagradáveis e degradações em óleos utilizados por longos períodos (ANS; MATTOS; JORGE, 1999). Durante o processo ocorrem mudanças físicas e químicas no óleo, dentre as mudanças físicas encontra-se: escurecimento, aumento na viscosidade, diminuição do ponto de fumaça e formação de espuma; já as mudanças químicas acontecem: i) hidrólise - forma ácidos graxos livres, monoacilglicerol e diacilglicerol, ii) oxidação - forma peróxidos, hidroperóxidos, dienos conjugados, epóxidos, hidróxidos e cetonas, iii) polimerização – em pequenos fragmentos ou permanecem na molécula do triacilglicerol e se associam, conduzindo a triacilgliceróis diméricos e poliméricos (SANIBAL; MANCINI-FILHO, 2002).

Além de mudanças físicas e químicas no óleo, ocorrem alterações no alimento frito. Dentre as alterações, deve-se destacar a formação de acrilamida. Substancia química que pode ser produzida em alguns alimentos preparados em altas temperaturas (ANVISA, 2002).

Muitos pesquisadores voltam sua atenção para o desenvolvimento de revestimentos comestíveis com propriedades benéficas e inovadoras para alimentos *in natura* ou pré-processados. Em contraste, poucos estudos sobre a otimização dos processos de secagem de revestimentos comestíveis aplicados em produtos alimentícios em nível industrial podem ser encontrados na literatura. Não é novidade que os revestimentos comestíveis requerem algum tempo para secar (FAKHOURI; GROSSO, 2003), mas as demandas por espaço, tempo e dinheiro precisam ser discutidas do ponto de vista industrial.

Considerando o grande consumo de batata na forma de batata frita é preocupante o aumento da ingestão de lipídios pela população mundial, bem como alimentos contendo teores de compostos carcinogênicos e tóxicos. Neste contexto, as investigações visando reduzir a absorção de óleos e gorduras em frituras, o estudo de tecnologias que direcionam redução de acrilamida em alimentos devem ser realizados.

Este trabalho teve por objetivo desenvolver coberturas comestíveis com base em três polímeros naturais para aplicação em batata palito para fritura, com o intuito de reduzir a absorção de óleo durante o processo de fritura, bem como a produção de acrilamida na batata frita. O trabalho é apresentado na forma de capítulos, descritos resumidamente a seguir:

O Capítulo 1, intitulado: "**Drying kinetics of French fries covered with soy protein/starch edible coatings**", é um capítulo de livro publicado com parte dos testes iniciais quanto a seleção de polímeros e cinética de secagem das coberturas comestíveis que seriam utilizados no desenvolver da pesquisa.

O Capítulo 2, intitulado: "**Avaliação dos polímeros utilizados para o desenvolvimento das coberturas comestíveis, bem como da temperatura e tempo de secagem das mesmas**", descreve os polímeros utilizados na pesquisa, o estudo dos tempos e temperatura de secagem de secagem, o processo de fritura e análise das batatas.

O Capítulo 3, intitulado: "**Influência das coberturas comestíveis nos diferentes ciclos de fritura contínua: absorção de lipídios, oxidação do óleo e quantificação de acrilamida**", descreve os ciclos de frituras em que foram submetidas as amostras de batata, caracteriza as amostras de batata, analisa a oxidação do óleo e verifica a formação e quantificação de acrilamida nas batatas fritas.

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CAPITULO 1

Chapter Book

Drying kinetics of French fries covered with soy protein/starch edible coatings

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ABSTRACT

The potato (*Solanum tuberosum*) is an annual herbaceous, growing up to 100 cm in height and produces a tuber that ranks as the fourth world food crop, after maize, wheat and rice. Although the United States is the fifth largest potato producer in the world, only a third of the potatoes is consumed fresh and 60% of annual output is processed into frozen products such as frozen French fries and wedges, crisps, dehydrated potato and starch. In Brazil, the annual consumption is around 14 kg per inhabitant, but this market is changing, particularly for processed potato snacks. The development of chronic non-communicable diseases is associated with several factors such as inadequate physical activity, excess intake of calories and fat, inadequate intake of vitamins and minerals, excessive alcohol consumption and genetics. The increase in the consumption of fried foods is critical, requiring alternatives to reduce the absorption of fats from fried foods. It is known that some edible coatings are able to reduce the oil absorption during the frying process (e.g.: coatings based on hydroxypropyl methylcellulose and whey; guar gum; carboxymethylcellulose and pectin; Basil seed gum of new hydrocolloid (BSG) and salep; whey protein and pectin in the presence of transglutaminase; methylcellulose). One of the limitations of the implementation of this technological innovation in the industry is that few studies focusing on the effect of different drying parameters on covered foods may be found in literature and, in most studies, the foods are dried at room temperature, which would require longer processing time. In this context, this book chapter aimed to study edible coatings based on natural polymers (soy protein-SPI and potato starch) considering the effect of process variables such as drying temperature and time. Kinetic modeling was used to study the drying behavior of potatoes after applying the coating. The Fick equation was considered to calculate the mass diffusivity.

Keywords: French fries, edible coatings, natural polymers, drying kinetics, mass diffusivity.

INTRODUCTION

Since early 1960, potato growing has rapidly surpassed all other food crops in developing countries and, at this moment, more than half of global potato output comes from developing countries. Potatoes are an excellent source of low-fat carbohydrates, presenting a quarter of the calories than bread. Potatoes are used for various purposes and not only as vegetables to cook at home. In fact, less than 50% of potatoes grown around the world are likely to be consumed fresh. The rest is processed into potato food products and food ingredients [CIP/USDA, 2016].

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Although potatoes are no longer the staple food of the past, they gain even more value from the nutritionist because of the nutrient density and contribution to a more balanced diet [BOHL & JOHNSON, 2010].

According to the US Department of Agriculture (USDA), potatoes may be considered a high-consumption food in the US diet and most of this food is sold in fast food restaurant chains, which achieved more than US$ 142 million sales in 2010 [NICKLE & PEHRSSON].

Vegetable oils play an important role in the food industry since they are able to improve the sensory characteristics of foods such as taste, odor and texture [FOX & KEYEYIAN, 2000]. The frying process has contributed to increasing of the consumption of oils and fats since it improves the palatability, generates sensory pleasant foods and is characterized by an easy manipulation [DEL RÉ & JORGE, 2006]. On the other hand, the correlation among the abusive consumption of vegetable oils and diseases such as obesity, hypertension, diabetes have been established in various studies [FOX & KEYEYIAN, 2000].

The relevance of ingestion of vegetable oils in the human diet, primarily as energy-supplying food resources, is unquestionable. In contrast, the risk of the development of chronic diseases requires a control of the qualitative and quantitative aspects of the quality of oils used in the frying process [DEL RÉ & JORGE, 2006]. When used appropriately in cooking preparations based on in natura or minimally processed foods, oils and fats contribute to diversifying and making foods more palatable without causing a nutritional imbalance [BRASIL, 2014].

The development of chronic noncommunicable diseases (eg, obesity, diabetes, hypertension, cardiovascular disease) is related to several factors such as inadequate physical activity, excessive intake of calories and fat, inadequate intake of vitamins and minerals, genetics, among others [MAHAN et al., 2012]. There are several studies that investigate the consumption of high fat foods and their relation to chronic noncommunicable diseases [CEMBRANEL et al., 2017; MESSIAS et al., 2016; CORREIA, 2016; RUNNING, MATTES, 2016].

Considering the great consumption of potatoes as French fries, it is worrying the increase of the lipid intake by the world population. In this context, investigations aiming to reduce the absorption of oils and fats in fried foods should be performed.

Edible coatings have been extensively used in the food industry, basically to extend the shelf life of some products. Sausages, for example, were initially coated by using animal intestines [LAWTON, 1996]. Since the twelfth century, the Chinese have applied wax in oranges and lemons to increase the shelf life of these fruits [JUNG et al. 1992].

The materials used in the preparation of these coatings are traditionally classified as hydrophobic and hydrophilic. Hydrophilic materials are characterized by polar covalent bonds and predominance of amino or hydroxyl and carboxyl groups, usually present appropriate solubility in aqueous medium, which facilitate the dispersion of the solute and a more homogeneous formation of the film. Depending on the chemical structure, they may form gels or even require chemical changes for a complete solubilization. Due to the affinity for water, they are more suitable for sliced surfaces, fruits with shiny aspects that show high wettability or presence of surface loads, preserving the hydrated aspect. Examples of such materials include polysaccharides (eg. cellulose, chitin, xanthan gum, guar gum, pectin, starch) and polyelectrolyte polysaccharides (eg. carboxymethylcellulose, chitosan, alginate) [ASSIS & BRITTO, 2014]. Lipophylic coatings, in turn, present appropriate gases and water barrier properties; however, the direct application of any lipid to a hydrophilic or wet surface results in weak adhesion at the film-food interface. Dual-coating may be an alternative for this problem, providing protection against more than one permeate by using different laminate layers [EMBUSCADO & HUBER, 2009].

Many researchers turn their attention to the development of edible coatings with beneficial, innovative properties for in natura or pre-processed foods. In contrast, few studies on the optimization of drying processes of edible coatings applied in food products at an industrial level may be found in the literature. It is not new that the edible coatings require some time to dry [FAKHOURI & GROSSO, 2003], but demands for space, time and money need to be discussed from the industrial point of view. With this in mind, in this book chapter, we decide to study the effect of drying parameters (time and temperature) during the coating of French fries. Two natural polymers, the soy protein isolated (SPI) and potato starch, were selected for the development of edible coatings.

LITERATURE REVIEW

1 Edible coatings

The edible films differ from the edible coatings because they are formed prior to their application to the product, while the coating forms during the application thereon [KROCHTA et al., 1994].

Edible films and coatings are classified according to the constitution in three different groups: i) hydrocolloids - based on polysaccharides or proteins, they are characterized by low permeability to oxygen, carbon dioxide and lipids [LABUZA & BREENE, 1989]; ii) lipids – present low water vapor permeability due to hydrophobic nature [GALUS & KADZINSKA, 2015]; iii) compounds - are based on a combination of proteins and lipids or polysaccharides and lipids, may exist as separate or associated layers, in which both components are added to the film [LABUZA & BREENE, 1989].

The coating is a formulation containing one or more macromolecules and additives, which is applied directly onto the food surface. After the drying step, the formation of a thin film on the product is observed [GENNADIOS & WELLER, 1990]. This layer of edible material is formed around the food or placed between the food constituents [KROCHTA & MULDER-JOHNSON, 1997].

1.1 Materials

For the preparation of edible and/or biodegradable films, various constituents should be considered, including a film-forming agent (macromolecules), solvent (water, ethanol, etc.), a plasticizer to attenuate stiffness (glycerol, sorbitol, among others) and, in some situations, pH regulating agents. Among the macromolecules, the main groups used are proteins, polysaccharides and derivatives, and lipids (monoglycerides, fatty acids, natural waxes) [BERTAN, 2003].

Polymers are macromolecules characterized by high molecular mass derived from the combination of one or more chemical units (monomers) that interact covalently [MANO &MENDES, 1999]. Polysaccharides such as starch, cellulose and chitin proteins are sources of renewable, biodegradable and low-cost resources. Among them, starch is probably the most promising material for the production of packaging, edible films, garbage bags due to low cost and its high biodegradability [COSTA, 2017].

Proteins of animal origin such as collagen, gelatin, casein, whey proteins as well as proteins of vegetable origin, such as zein, derived from corn, isolated soy protein and the wheat gluten protein have been extensively used for the preparation of films and edible coatings [LAWTON, 1996]. Gluten proteins can be divided into two main fractions according to the solubility in aqueous alcohols: the soluble gliadins and the insoluble glutenins. While the gliadin corresponds to the viscous component of gluten, the glutenin contributes to the elastic properties [McHUGH & SENESI, 2000].

Brazil is the second largest producer of soy in the world, behind only the United States. In the 2014/15 crop, annual soy production was estimated at approximately 315 million tons [USDA, 2015] and the largest producing regions are the Midwest and the South. It is used in several sectors of the economy due to its high commercial competitiveness. Several by-products such as oil, a flour and its protein isolate (soy isolated protein - SPI) may be extracted from the soy, each one with an importance in a specific field.

Proteins are high molecular weight biological molecules of amino acids linked together by peptide bonds. The amino acids contain in their molecular structure at least one primary amino group ($-NH_2$) and one carboxylic group (-COOH). Moreover, each amino acid has a characteristic (R) side chain, which affects the physicochemical properties and protein properties [BOBBIO & BOBBIO, 2003]. Among the biopolymers, proteins have functional and structural properties that allow the application as the main matrix in the structure of films and biodegradable and edible coverages [CHO et al., 2007; DENAVI et al., 2009].

Soy protein isolate has received wide attention due to the low oxygen permeability when compared to the traditional low-density polyethylene film [BRANDENBURG et al., 1993; CUQ et al., 1998], offering opportunities to preserve food from oxidative deterioration. Moreover, SPI present a low cost and is a rich source of high-quality proteins, presenting appropriate biodegradability and biocompatibility properties [CAO et al., 2007a; SUI et al. 2012; WANG et al., 2012].

Various studies can be found in the literature on the properties and applications of SPI [BRANDENBURG et al., 1993; CHOI et al., 2003; GENNADIOS et al., 1993; WANG et al., 2016; KIM et al., 2003; PARK et al., 2001; WANG et al., 2012; WIHODO & MORARU, 2013; ZHANG et al., 2010]. Ghidelli et al. [2015], for example, prepared SPI-based edible coatings and considered a modified atmosphere packaging to extend the shelf life of fresh-cut 'Blanca de Tudela' artichoke. In another study, the performance of edible coatings containing SPI alone or combined with carboxymethyl cellulose (CMC) on the reduction of moisture loss of apples and potatoes was evaluated. Edible coatings combined with CMC showed to be more effective, avoiding the moisture loss over 5 days. During the preparation of the coating material, the formation of an oil-in-water emulsion was observed, which provided a hydrophobic surface responsible to reduce the moisture loss from studied material [SHON & CHOI, 2011]. The formation of an emulsion on the surface of foods has relevant commercial appeal. The use of a mixture of fat and carbohydrate constituents emulsified by protein allows a direct adhesion of hydrophilic carbohydrate at food surface and formation of a hydrophobic layer or coating at the external food surface [EMBUSCADO & HUBER, 2009].

As starch is one of the most remarkable and abundant polysaccharides found in nature, is cheap and highly biocompatible, it has been the source of several investigations exploiting its ability to form coatings for applications in the food industry [ARVANITOYANNIS et al., 1998].

Starch is a natural polymer found in vegetables, composed of several glucose molecules, which represent the primary energy reserve in higher plants. Although various plants accumulate starches, the most economically viable and most widely used in the market for this purpose are cereals and roots, such as corn, wheat, potatoes and cassava. Starch is the amylaceous product extracted from edible aerial parts of plants (seeds, etc.) or edible underground parts of plants (tubers, roots and rhizomes) [CEREDA et al., 2001; PETERSEN et al., 1999].

Glucose residues are linked by only two types of glycosidic bonds, α-(1→4) and α-(1→6) glycosidic linkages, characterizing two main macromolecular arrangements, the amylose and amylopectin (Figure 1). While the amylose is essentially a linear α-(1→4)-D-glucan polymer, the amylopectin is a highly branched and slightly phosphorylated macromolecule consisting of α-(1→4)-D-glucan short chains connected through α-(1→6) linkages [BULÉON et al., 1998; TESTER et al., 2004].

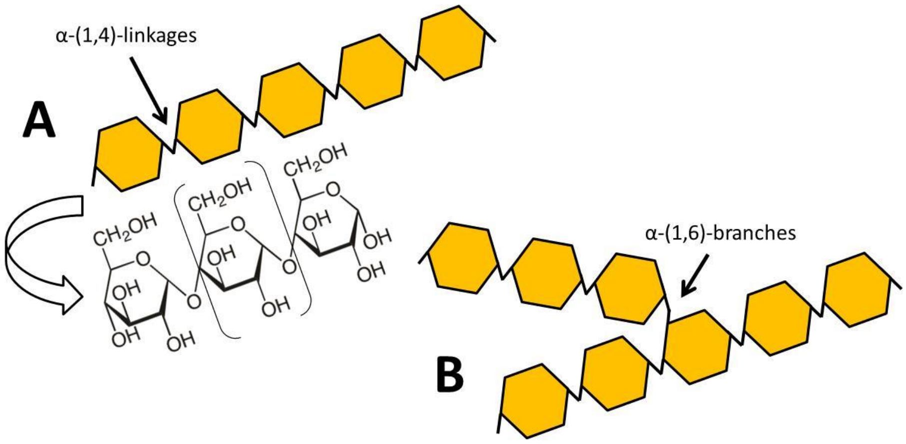

Figure 1. Structures of (A) linear amylose and (B) branched amylose and amylopectin.

The amylose content in the starch varies from 18 to 30%, providing different properties for the starch [LERDTHANANGKUL & KROCHTA, 1996]. The quality of edible films is improved as the amylose content increases [PETERSEN et al., 1999]. Due to the hydrophilic character, films or starch-based coatings have reduced water vapor barrier properties, but approaches such as combination with other film-forming agents or structural rearrangements and chemical modifications have been considered in order to improve the stability of these films and coatings to moisture [PETERSEN et al., 1999]. The addition of plasticizers, such as sorbitol and glycerol, to films and coatings based on corn starch and potato starch, for example, improved the water vapor barrier properties. Coatings without plasticizer are characterized by generating more crystalline and brittle structures, resulting in significantly higher water vapor permeability values due to the presence of pores and cracks [GARCÍA et al., 1999]. Starch-based films also exhibit appropriate mechanical properties and oxygen barrier properties [RINDLEY et al., 1998].

A fine, tasteless powder with “excellent mouth-feel,” the potato starch provides higher viscosity than wheat and maize starches and makes the product tastier. It is used as a thickener for sauces and stews, and as a binding agent in cake mixes, dough, biscuits, and ice-cream [CIP, 2017].

Plasticizers are, in general, high boiling point liquids with average molecular weights of between 300 and 600 Da, and linear or cyclic carbon chains. Due to the low molecular size, the plasticizers are distributed in the intermolecular spaces between polymer chains, reducing secondary forces among them. At the same time, these constituents change the molecular organization of polymers, reducing the energy required for molecular motion and the formation of interchain hydrogen bonding. As a consequence, an increase in the free volume and in the molecular mobility is observed, impacting on the flexibility of film [VIERA et al., 2011]. Polyols such as sorbitol and glycerol have been found to be particularly effective for application in the formulation of edible coatings, presenting a direct impact on mechanical resistance and flexibility due to the reduction of intermolecular forces among the polymer chains [KROCHTA & DeMULDER-JOHNSTON, 1997; McHUGH & KROCHTA, 1994a].

1.2 Applications

Edible coatings represent an environmentally friendly technology applied on products to control the migration of moisture, oxygen, carbon dioxide, aromas, and lipids. Moreover, they can also incorporate additives into foods such as antioxidants, antimicrobials and aroma, enhancing the mechanical integrity and/or handling characteristics of a food product [KROCHTA & MULDER-JOHNSON, 1997].

It is known that the application of some edible coatings reduces the absorption of oils during the frying process. This surface treatment reduces the surface porosity and also creates a barrier against oil absorption. Edible coatings prepared with hydroxypropyl methyl cellulose and whey [BERBARI, et al., 2011], guar gum [SOTHORNIV, 2011], carboxymethylcellulose [GARAH, et al., 2004], a protein derived from fresh basil gum (BSG) and salep [KARIMI et al., 2016], serum protein and pectin in the presence of transglutaminase [ROSSI MARQUES et al., 2014], methylcellulose [FONTES, 2009] have been reported for this purpose. Cellulose derivatives have been more effective, which may be associated with its more hydrophilic nature and fat barrier characteristics [GARCIA et al., 2012]. Hydroxypropyl methylcellulose-based coatings, for example, lead to the formation of a gel layer after heating, which provides a moisture retention and also avoids the oil absorption. When the temperature is reduced, the polymer returns to its original state [SARMADIZADEH et al., 2011].

The properties of the food surface have great importance in the incorporation level of fats, which makes the application of coatings a promising approach. The increased surface roughness, for example, leads to increased oil uptake. The coating may be thin and invisible, or it may be thick, called "batters". Although the action mechanism of coatings in the reduction of fat absorption is usually not clarified, properties such as low moisture permeability, thermogelling or crosslinked are desirable to reduce the absorption of these constituents [MELLEMA, 2003].

Overall, protein-based films have remarkable gas barrier properties compared with those from lipids and polysaccharides. Moreover, protein-based edible films improve mechanical properties since proteins are characterized by high intermolecular interactions. Soy protein is a side-product of soybean oil industry and development of biodegradable films has the potential to add value to this constituent [NANDANE & JAIN, 2015]. SPI-based edible coatings have been applied to fruits such as strawberry [AMAL et al., 2010] and apple [Baldwin et al., 1996] as well as vegetables such as potato [BALDWIN et al., 1996].

Starch-based edible coatings have the advantage of lower cost compared to other alternative high tensile strength materials. In native starch granules, amylose and amylopectin molecules are packaged into semi-crystalline aggregates, providing greater stiffness for the coatings prepared with these materials. When a chemical substitution or acid hydrolysis of amylose-containing starches is considered, coatings are characterized by improved clarity and flexibility [KARMER, 2009]. The application of starch-based edible coatings have been considered in fruits such as grapes [FAKHOURI et al., 2007], guava [SOARES et al., 2011], pear [BOTREL et al., 2010], banana [CEREDA, 1995], papaya [CEREDA et al, 1992] as well as in vegetables such as chili [VICENTINI et al., 1998].

2 Potatoes market information

After rice and wheat, potatoes are the most important food crop in the world in terms of human consumption. More than one billion people worldwide eat potatoes, and the total global crop production exceeds 300 million metric tons. The potato (*Solanum tuberosum*) belongs to the Solanaceae family, both originated and domesticated for the first time in the South American Andes [CIP/USDA, 2016].

Fresh potatoes are cooked, boiled or fried and used in an impressive variety of recipes: mashed potatoes, potato pancakes, potato chips, twice roasted potatoes, potato soup, potato salad and potato gratin. One of the major items in this category is frozen potato, which includes most of the fries served at restaurants and fast food chains around the world [CIP].

The United States is the fifth largest potato producer in the world, achieving a total production of almost 20 million tons in 2013 [FAO, 2015]. In addition, there is a great demand for the industry that produces commodities such as chips and frozen chips, for local and foreign markets, generating significant flows of income for the agricultural companies involved [PERTASAKOS et al., 2016].

Only a third of US potatoes are consumed fresh. Approximately 60% of annual output is processed into frozen products (such as chips and frozen slices), potato chips, dehydrated potatoes and starch [FAO, 2008]. In 2011, 40% of the potatoes were consumed as frozen pre-fried potatoes, 29% fresh market, 15% as potato chips, among others. The consumption per inhabitant was 51 kg in 2011 [Ed MISSIAEN].

In Brazil, potatoes are still a minor crop for the Brazilian agriculture. The country is the second largest producer of potatoes in Latin America [FAO, 2008], presenting an estimated production of 3.6 million tons/year [IBGE, 2016; SOUZA et al., 2013]. Consumption is estimated at 14 Kg per inhabitant; however, Brazil is considered an award-winning market for processed potato snacks [FAO, 2008].

The freezing of pre-fried potatoes (French fries) is another method of industrialization of the potato, which can be processed at times of harvest considering the greater production volume and improved quality of the raw material. This procedure allows that the frozen pre-fried potato can be found in volumes proportional to the demand during low production periods. As a consequence, lower price oscillations throughout the year are observed [GOMES, 1997].

3 Process of frying

Deep fat frying is a cooking method that can be used to cook foods such as fried chicken, French fries, and potato chips. The process involves the immersion of foods in extremely hot oil until it reaches a safe minimum internal temperature. When the food is deep-fried properly, it will be hot and crispy on the outside and cooked safely in the center. Deep frying is very fast and destroys bacteria when performed properly [USDA, 2012]. The application of high heat transfer rates during the deep-fat frying is responsible for the development of attractive sensorial attributes of fried potatoes. Potatoes having high solids content (20–22%) are preferred for frying because they result in better texture, higher yields, and lower oil absorption in the finished product [PEDRESCI, 2012].

During the frying, a simultaneous process of heat and mass transfer is observed. Heat is transferred from the oil for food; water evaporating from food is absorbed by the oil. Thus, factors that affect heat transfer and mass also are able to affect the thermal and physical-chemical properties of both oil and food [MONGHARBEL, 2002].

The frying process is performed in open containers at high temperature (180-200°C). Due to contact with the atmosphere gases, chemical reactions such as thermo-oxidation and rancidity may be observed; changing the viscosity, foaming of the medium where the oil was added. These events affect the sensory characteristics of the oil as well as the acceptability of the fried product. When rancid products are ingested continuously, phenomena such as irritation of the gastrointestinal tract, inhibition of enzymes, destruction of vitamins and carcinogenesis may be observed [DOBARGANES, 1989; FRITSCH, 1981; STEVENSON et al., 1984].

Edible oils represent one of the main sources of energy used during the preparation of daily foods. The edible oils can be added as an ingredient or used in the frying process, where they can develop odor, flavor, color and texture characteristics that make food more attractive for consumption. Part of this oil/fat used as heat transfer medium is also absorbed by the food, becoming an ingredient of the product of human consumption [CELLA et al., 2002; ANS et al., 1999; LIMA & GONÇALVES, 1994].

The selection of a suitable oil for the frying is extremely relevant not only for its nutritional value but also for its ability to support frying conditions. During frying, oil deteriorates after exposure to heat, water, and oxygen exposure. As a consequence, complex chemical reactions contribute to increasing the number of lipid degradation compounds in oil bath such as free fatty acids, mono and diglycerides and polymers, which are potentially toxic carbonyl compounds. These compounds may be absorbed by the food, reducing its nutritional properties/value [ZIAIIFAR et al., 2008].

4 Drying

Drying is mass transfer process consisting of the removal of water and other liquids from process materials. Drying, in general, usually means removal of relatively small amounts of water from the material. Evaporation refers to the removal of relatively large amounts of water from the material. In evaporation, the water is removed as the vapor at its boiling point. In drying, the water is usually removed by air as a vapor [GEANKOPLIS, 1993]. In this situation, drying is used to create a dried surface material matrix around the product. Once this method reduces the total water content in food, the oil absorption is limited during the frying [ZIAIIFAR et al., 2008].

Drying methods can be classified as the batch or continuous drying. In the batch dryer, the material is inserted into the drying equipment and drying proceeds for a given period of time. The batch dryer is recommended for small lots and for use in multiple-product plants. In the continuous drying, the material is continuously added to the dryer and dried material continuously removed [GEANKOPLIS, 1993]. The drying constant depends on both material and drying air properties. The effect of air temperature, relative humidity, air velocity and material size should be considered during the optimization of drying parameters and selection of equipment for each studied material [KROKIDA et al., 2003].

MATERIALS & METHOD

- Materials and chemicals

The potatoes (*Solanum tuberosum 'Doré'*) were purchased from the local market (Dourados, Brazil). Commercial soy protein isolate containing 900g/kg protein, was obtained from Solae® (Americana, Brazil). Potato starch (Yoki®) were purchased from a local market (Pouso Alegre, Brazil). Glycerol and sodium metabisulphite were obtained from Labsynth (Diadema, Brazil) and Dinâmica Química Contemporânea Ltda® (Diadema, Brazil), respectively.

- Film-forming solution

SPI and starch solutions were prepared separately.

For the soy protein isolated (SPI) solution, 18 g of SPI were initially solubilized in 300mL of distilled water. A glycerol amount of 40% (w/w) in relation to SPI was added. The pH of the solution was adjusted to 10. The solution was maintained under continuous stirring for 1h at 70°C.

For the starch solution, 5g of potato starch was initially solubilized in 100 mL of distilled water. A glycerol amount of 2% (w/w) in relation to starch was added. The solution was solubilized in the water bath for 3min at 90°C.

Five coatings containing different concentrations of SPI and starch were prepared. Uncoated potatoes were used as the control (Table 1).

Table 1. Concentrations of edible coatings.

Formulation	SPI solution mL/100mL	Starch solution mL/100mL
Control	0	0
100% SPI	100	0
75% SPI	75	25
50% SPI	50	50
25% SPI	25	75
100% Starch	0	100

- Preparation of samples

The potatoes were sanitized in 0.1% chlorinated solution for 15 minutes, peeled, cut into a manual cutter with a thickness of 0.8 x 0.8 x 6 cm and then immersed in a 0.2% antioxidant solution for 10min. After that, the potatoes were centrifuged for 30s before application of the edible coatings. Potatoes were immersed in the coating solutions for 1 min. Figure 2 shows the practical sequence of preparation and application of the edible coatings.

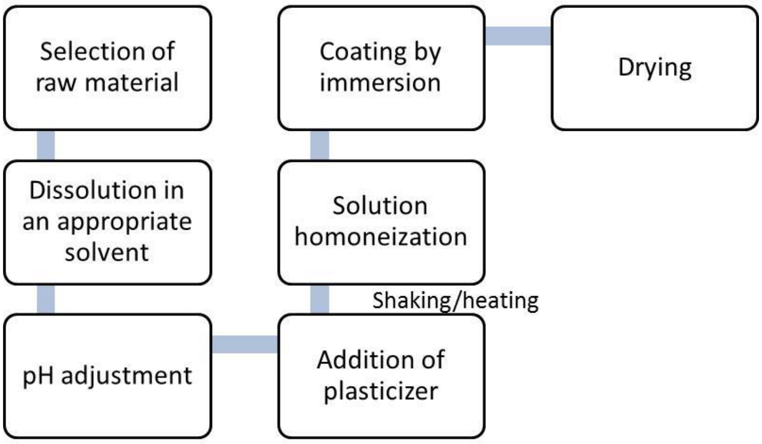

Figure 2. Steps involving the application of edible coatings on potatoes.

- Kinetics of drying

The assays to determine the effect of air temperature and edible coatings on the drying constant were carried out at 50, 60 and 70^{o}C. The drying assays were completed when the mass of samples was kept constant, which was assumed as the stage of dynamic equilibrium.

During the drying, the mass loss of the samples was measured every 15 minutes in the first two hours, every 30 minutes in the third and fourth hour, every hour from the fifth hour until constant weight was obtained [GEANKOPLIS, 1993].

The experimental data were adjusted in the mathematical models of drying presented in the Table 2. The dimensional free moisture (DFM) content was calculated according to the equation below:

DFM = $(X_t - X_e/X_{ti} - X_e)$

Where: X_t, is the water content over time t, X_e is the equilibrium moisture content and X_{ti} is the initial water amount.

Table 2. Mathematical models used to describe the drying kinetics

Model name	Model equation
Midilli	$M_R = a \exp(-kt^n)+bt$
Page	$M_R = a \exp[-(kt)^n]$
Henderson and Pabis modified	$M_R = a \exp(-kt)+b\exp(-gt)+c\exp(-ht)$
Verma	$M_R = a \exp(-kt)+(1-a)\exp(-gt)$

MR, experimental moisture ratio; a, b, c, g, h, coefficients and n, drying exponent specific for each equation; k, drying constant; t, time.

RESULTS & DISCUSSION

The drying rate curve as a function of moisture content (Figure 3) is characterized by three main stages: (1) transient early stage, during which the product is heating up; (2) constant rate period, where the moisture is relatively easy to remove; (3) falling rate period, in which moisture is bound or held within the solid matrix [MARCINKOWSKI, 2006; RAHMAN, 2007]. During the constant rate period, the presence of a thin film of water on the food is considered and there is not internal or external mass transfer resistance. In this stage, drying is controlled by external heat transfer. In the falling rate period, drying is controlled by the internal mass transfer resistance. The drying rate curve is affected by the type of material to be dried as well as the type of mass transfer that is controlling. For solids which the mass transfer is completely controlled by internal diffusion or completely hygroscopic biological solids, no constant drying period is observed [HARISSON, 2003].

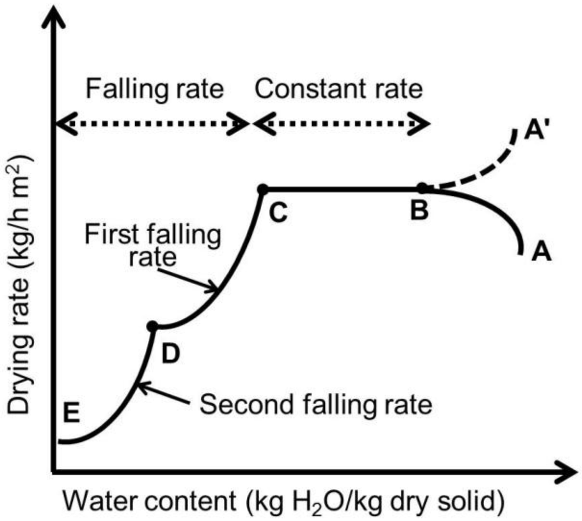

Figure 3. Drying rate curve as a function of moisture content. A-B: initial adjustment period; B-C: constant rate; C-D: first falling rate period; D-E: second falling rate period. The moisture content at the point when the drying period changes from a constant to a falling rate can be considered as the critical moisture content

The drying curves of the potatoes, at different temperatures, showed a descending behavior (C-D and D-E points). The point AB, which corresponds to the transition period, was not observed and the constant rate (B-C) was extremely difficult to visualize. In the previous step to prepare the raw material to be coated by using centrifugation, the surface moisture of the potatoes is removed, affecting the achievement of a constant rate (B-C). Similar results were obtained for the drying of okra [GOGUS & MASKAN, 1999], red bell pepper [GUPTA et al., 2002] and yellow passion fruit bagasse [MENEZES et al., 2013]. In addition, changes in the internal moisture and the addition of the edible coatings may also explain these results. The edible coatings generate a physical barrier to moisture, affecting the interaction between food and external environment. In another study evaluating the effect of different parameters of a forced convective dryer (air temperature, air velocity) on drying behavior of potatoes, no constant drying rate period was also achieved [NADERINEZHAD et al., 2016]. In the assays, the authors considered similar drying temperatures (45–70°C) those used in our study and attributed the lack of the constant rate period of drying to changes in the internal moisture, which sustain our findings.

The main models used to foodstuffs were applied to our experimental data. A satisfactory adjustment was achieved for the proposed models. Tables 3 to 8 show the statistical values of the coefficient of determination (R^2) and error quadratic average (MSE) for the models adjusted which considered the drying kinetics of potatoes at different temperatures. The Midilli model presented the best values in terms of the coefficient of determination (R^2) and error quadratic average (MSE), followed by the Page model.

Table 3. Coefficient of determination (R^2) and error quadratic average (MSE) calculated to verify which mathematical model presents the best fit to the experimental values. Drying curves of *Solanum tuberosum* coated with 100% SPI were obtained at 50, 60 and 70°C.

Mathematical Models	R^2 (decimal)			MSE (decimal)		
	50ºC	60ºC	70ºC	50ºC	60ºC	70ºC
Midilli	0.99832	0.99658	0.99792	0.0002	0.00030	0.00019
Page	0.99926	0.99626	0.99757	0.0002	0.00038	0.00026
Henderson and Pabis modified	0.99574	0.98975	0.98581	0.0003	0.00078	0.00113
Verma	0.98799	0.99046	0.98539	0.0012	0.00092	0.00148

Table 4. Coefficient of determination (R^2) and error quadratic average (MSE) calculated to verify which mathematical model presents the best fit to the experimental values. Drying curves of *Solanum tuberosum* coated with 75% SPI were obtained at 50, 60 and 70°C.

Mathematical Models	R^2 (decimal)			MSE (decimal)		
	50ºC	60ºC	70ºC	50ºC	60ºC	70ºC
Midilli	0.99850	0.99736	0.99640	0.00013	0.00022	0.00031
Page	0.99836	0.99716	0.99605	0.00016	0.00028	0.00039
Henderson and Pabis modified	0.99430	0.99631	0.99911	0.00042	0.00027	0.00007
Verma	0.98871	0.99343	0.99604	0.00106	0.00061	0.00037

Table 5. Coefficient of determination (R^2) and error quadratic average (MSE) calculated to verify which mathematical model presents the best fit to the experimental values. Drying curves of *Solanum tuberosum* coated with 50% SPI were obtained at 50, 60 and 70°C.

Mathematical Models	R^2 (decimal)			MSE (decimal)		
	50ºC	60ºC	70ºC	50ºC	60ºC	70ºC
Midilli	0.99823	0.99627	0.99613	0.00017	0.00034	0.00034
Page	0.99769	0.99561	0.99581	0.00025	0.00046	0.00043
Henderson and Pabis modified	0.99323	0.98826	0.99402	0.00058	0.00090	0.00046
Verma	0.99779	0.98928	0.98852	0.00023	0.00105	0.00110

Table 6. Coefficient of determination (R^2) and error quadratic average (MSE) calculated to verify which mathematical model presents the best fit to the experimental values. Drying curves of *Solanum tuberosum* coated with 25% SPI were obtained at 50, 60 and 70°C.

Mathematical Models	R² (decimal)			MSE (decimal)		
	50ºC	60ºC	70ºC	50ºC	60ºC	70ºC
Midilli	0.99864	0.99687	0.99502	0.00012	0.00026	0.00045
Page	0.99841	0.99652	0.99432	0.00016	0.00034	0.00059
Henderson and Pabis modified	0.99582	0.99699	0.99257	0.00034	0.00021	0.00058
Verma	0.99395	0.99459	0.98888	0.00059	0.00049	0.00109

Table 7. Coefficient of determination (R^2) and error quadratic average (MSE) calculated to verify which mathematical model presents the best fit to the experimental values. Drying curves of *Solanum tuberosum* coated with 100% starch were obtained at 50, 60 and 70°C.

Mathematical Models	R² (decimal)			MSE (decimal)		
	50ºC	60ºC	70ºC	50ºC	60ºC	70ºC
Midilli	0.99832	0.99727	0.98904	0.00015	0.00024	0.00109
Page	0.99777	0.99657	0.98900	0.00024	0.00034	0.00125
Henderson and Pabis modified	0.99063	0.99353	0.97629	0.00076	0.00048	0.00203
Verma	0.99061	0.99434	0.97095	0.00095	0.00053	0.00311

Table 8. Coefficient of determination (R^2) and error quadratic average (MSE) calculated to verify which mathematical model presents the best fit to the experimental values. Drying curves of *Solanum tuberosum* (without coatings; control) were obtained at 50, 60 and 70°C.

Mathematical Models	R² (decimal)			MSE (decimal)		
	50ºC	60ºC	70ºC	50ºC	60ºC	70ºC
Midilli	0.99762	0.99741	0.99797	0.00022	0.00022	0.00020
Page	0.99723	0.99733	0.99753	0.00029	0.00026	0.00028
Henderson and Pabis modified	0.98873	0.99268	0.97940	0.00090	0.00053	0.00178
Verma	0.98867	0.99305	0.98129	0.00114	0.00065	0.00202

Information from the drying curves (Figure 4, 5 and 6) is crucial for the development of dryer processes and equipment. From these drying curves, it is possible to estimate the drying time of a pre-defined amount of products and thus the energy spent in the process, which has a direct impact on the process cost and product price. In equipment design, this information is useful to define the operating conditions for drying as well as determining the type of heat exchangers, fans and other devices [VILELA & ARTUR, 2008].

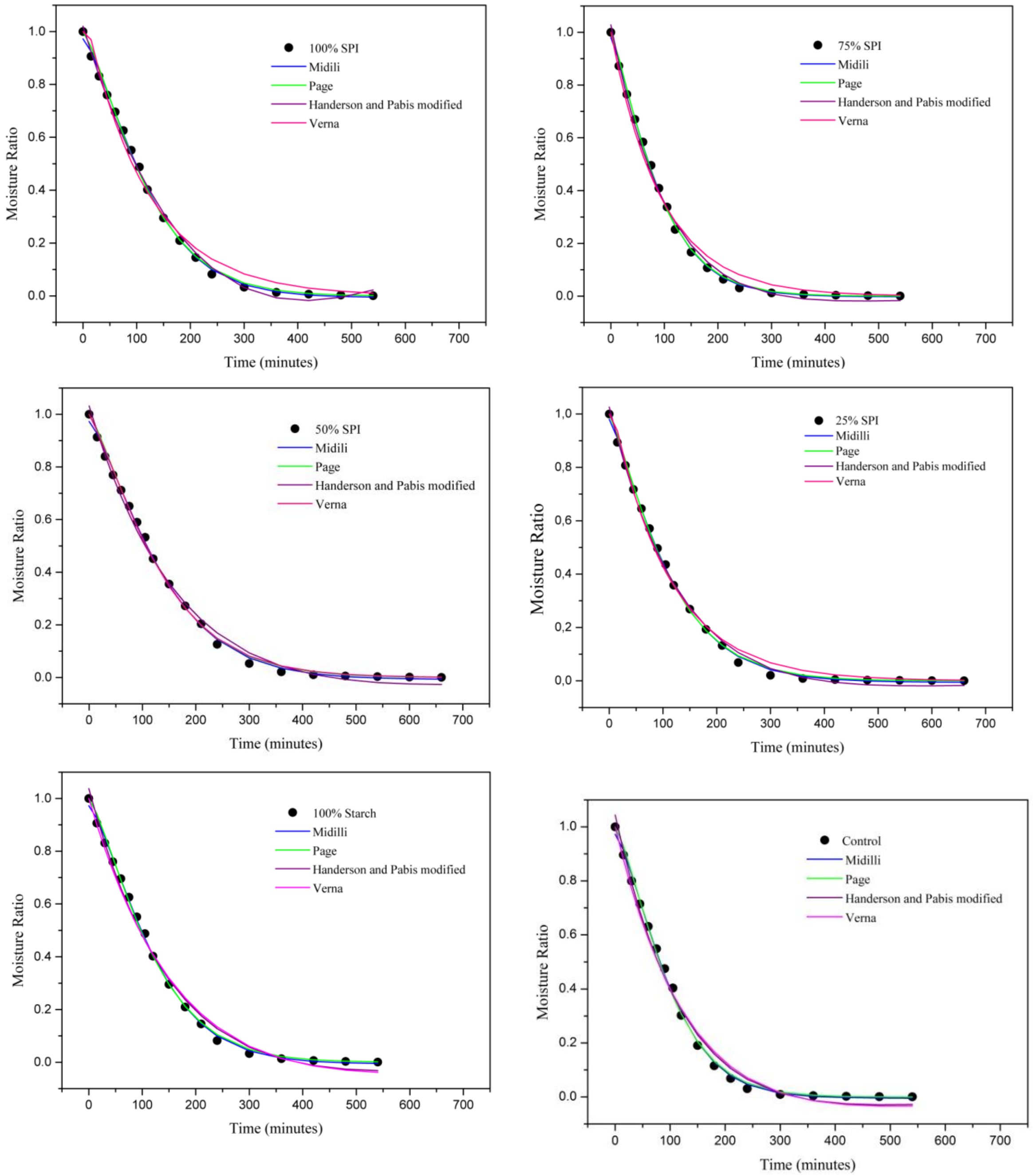

Figure 4. Drying of potatoes containing edible coatings at 50^{o}C.

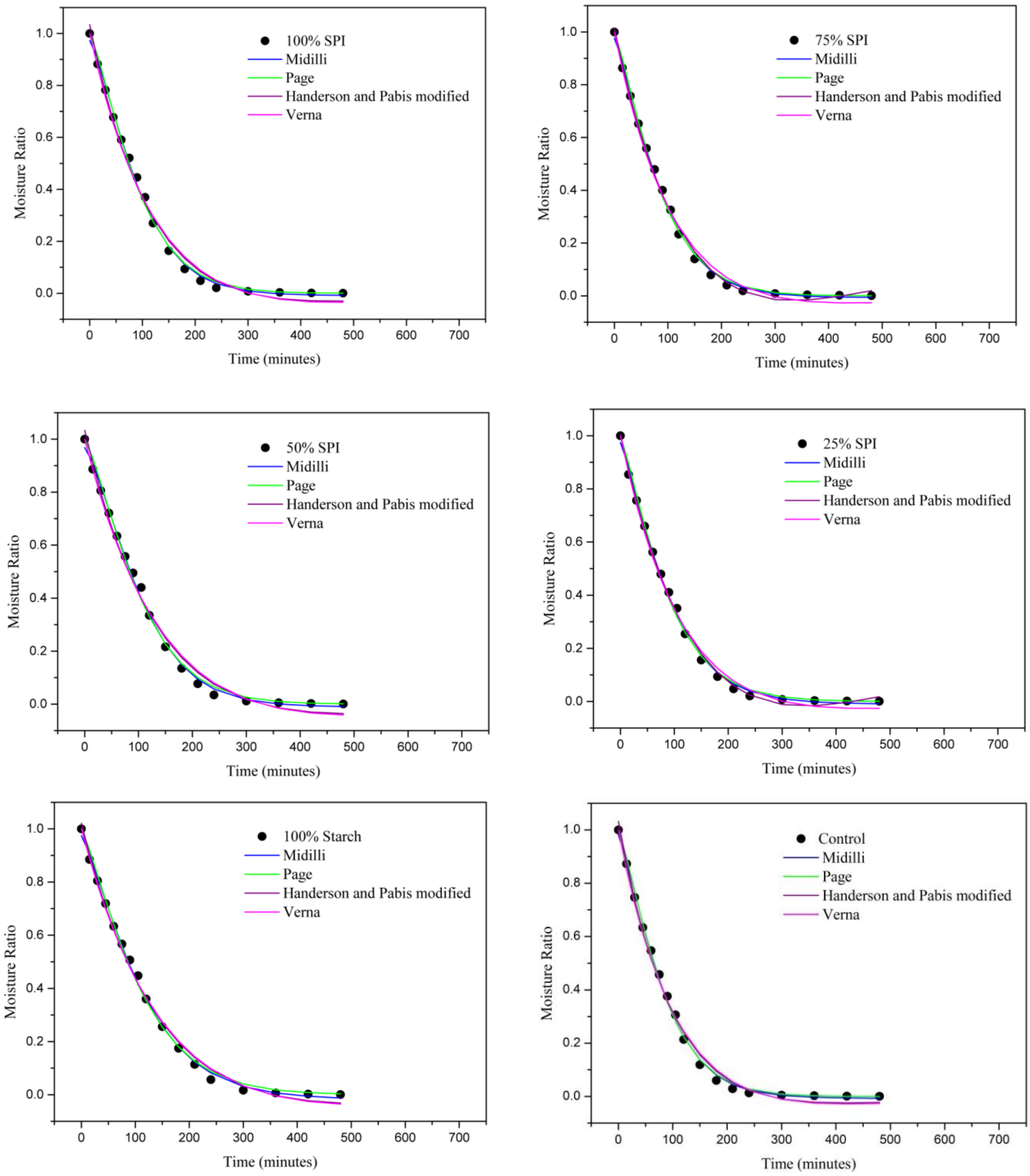

Figure 5. Drying of potatoes containing edible coatings at 60°C.

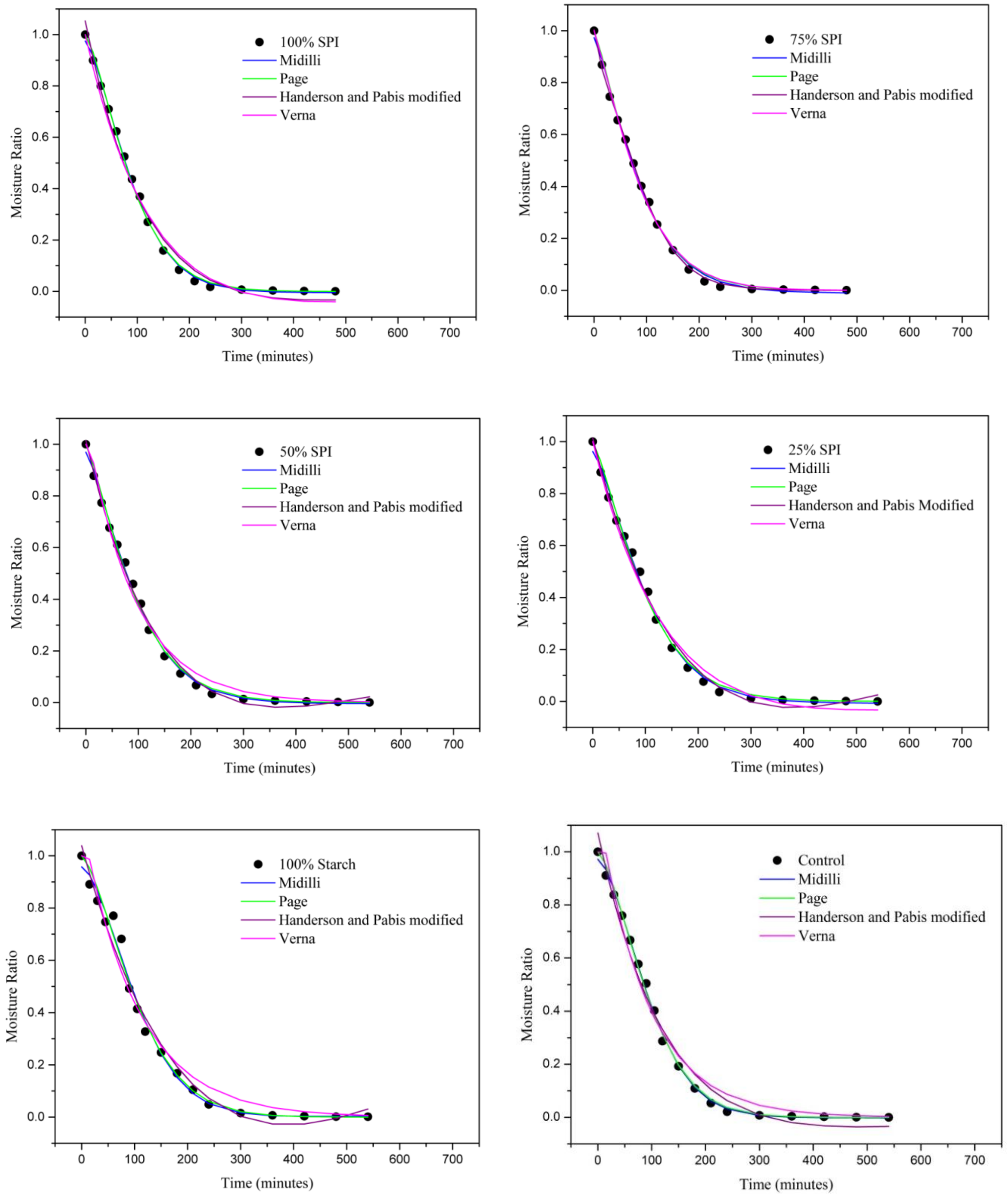

Figure 6. Drying of potatoes containing edible coatings at 70^{o}C.

Several studies have demonstrated that the drying temperature affects the drying rate for different samples, where the drying time reduces with increasing temperature [NUNES et al., 2014; MENEZES et al., 2013; SANTOS et al., 2010]. In the present study, when the temperature increased from 60 to 70^{o}C, the drying rate was not changed significantly. The high intrinsic moisture of the raw material could be the reason for this finding.

The profile of the drying curves did not show a significant reduction of the water contents as the drying temperature increased. Once the potatoes used in the study were characterized by high internal water content and low water loss, this would contribute to explain the occurrence of no significant differences when the temperature was changed. In the study of Sarmadizadeh et al. (2011), potato strips were coated with SPI and plasticized with sorbitol and high water retention was achieved (close to 80%). The hydrophobicity of SPI may explain this low water loss by vegetable. Moreover, a reduced surface area for the Frech fries compared to chips could justify a low evaporation rate, not discriminating the effect of the drying temperature. Naderinezhad et al. (2016), in their studies, verified that the lateral surface area presents a crucial role during the drying process of potatoes.

The main difference among the temperatures was the approximate time for the water content to reach equilibrium, which was 9-10, 8-9 and 7-8 h at 50, 60 and 70^{o}C, respectively. The higher the temperature the faster the achievement of the break-even point. These observations are important for the optimization of potato drying systems with industrial applications, where an ideal time and temperature are selected so that the product preserves the properties which ensure an efficient fried. At the same time that a reduction of oil absorption is expected, the product should maintain its nutritional properties. Very dry potatoes became softer products after fried due to structural changes. According to Pedreschi (2012), cells in the crust of fried potato strips tend to change the original shapes during the frying as a result of starch swelling and water migration.

Drying through air involves a simultaneous transfer of heat and mass as well as the amount of movement as the heated dry air which feeds the dryer is responsible for heating the product and the water released therefrom. When the resistance to transfer the water vapor from the surface of the product to the air is small, the diffusion of the water from the interior of the food controls the drying speed. The drying behavior of each solid differs in the mechanism of migration of moisture both inside the solid and in the air in contact with the surface [MARCINKOWSKI, 2006].

The graphical behavior of the drying curves among the tested conditions was quite similar. The drying process basically occurs in the period of decreasing rate, without clear evidence of drying at a constant rate, which may be explained by nature of the potato and pre-treatment approaches performed with the samples. Even in presence of free surface moisture, the water can be in the form of cell suspension and solution, presenting a vapor pressure lower than that of pure water.

More relevant changes associated with temperature were observed for samples composed of 50 and 100% (w/w) SPI and 100% starch. In a study evaluating the thermal properties of soybean protein isolates/starch mixtures, SPI in the blend restricted the starch gelatinization, while the presence of starch protected the SPI from denaturation. No chemical reaction between SPI and starch were observed when they were heated from 20 to 130 °C (involve our studied temperature range). As a consequence, more thermally stable coatings would be obtained when these constituents are combined [LI et al., 2014]. In coatings prepared with 100% (w/w) SPI or 100% starch, they would be less thermally stable, justifying the greater influence of the drying temperature. Once the drying curves did not present drastic fluctuations, it is possible to state that the drying procedure without dryer was homogenous. A moisture loss faster was observed at the beginning of the drying process (an exponential reduction). Overall, high temperatures contribute to increasing the drying rate.

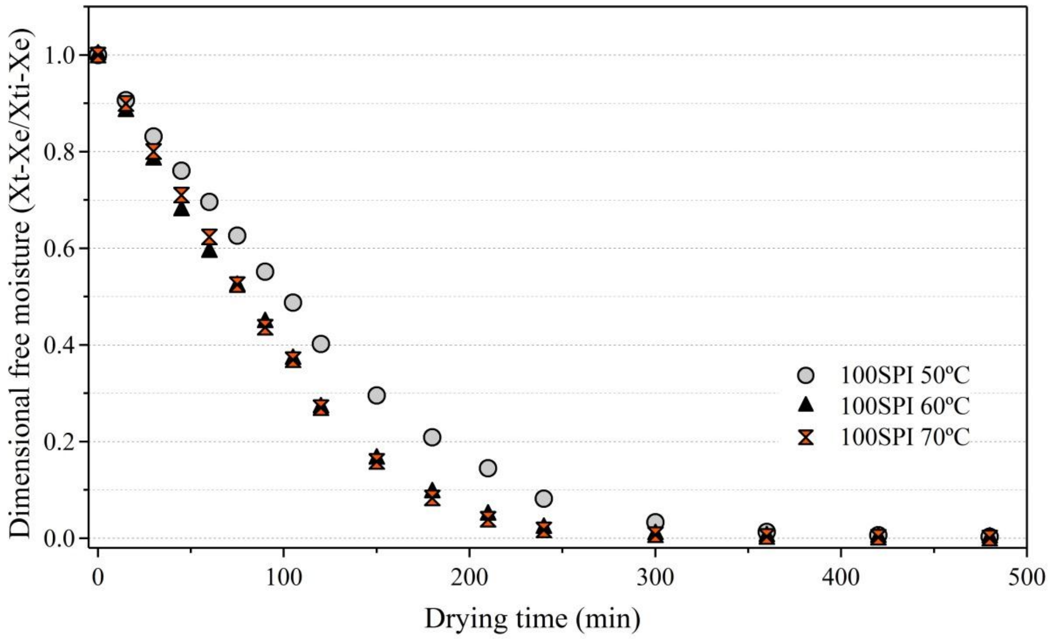

Figure 7. Effect of drying temperature for the sample containing 100% SPI.

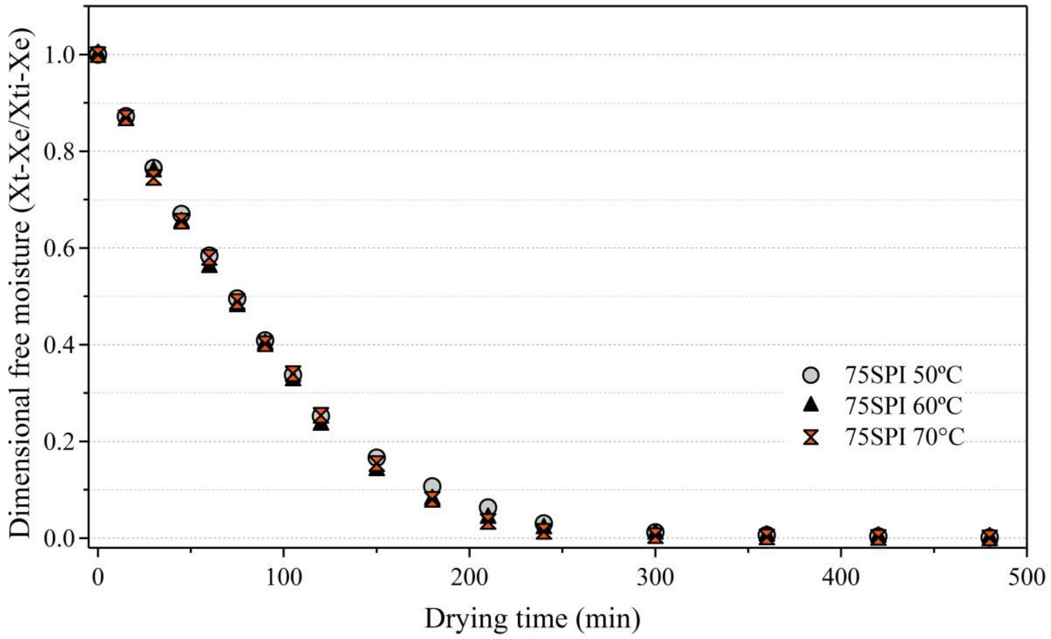

Figure 8. Effect of drying temperature for the sample containing 75% SPI.

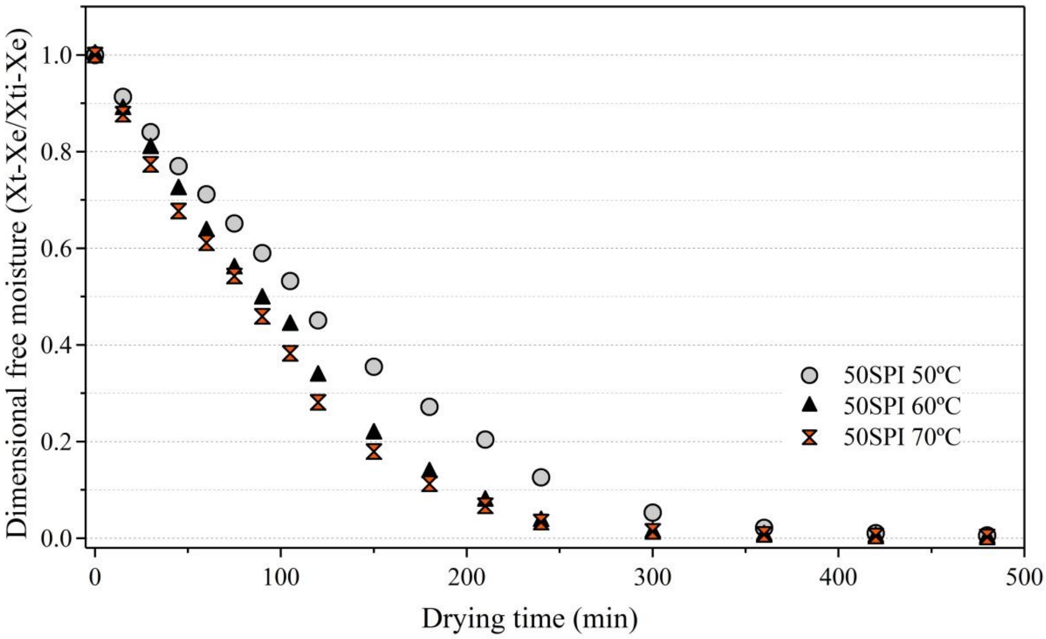

Figure 9. Effect of drying temperature for the sample containing 50% SPI.

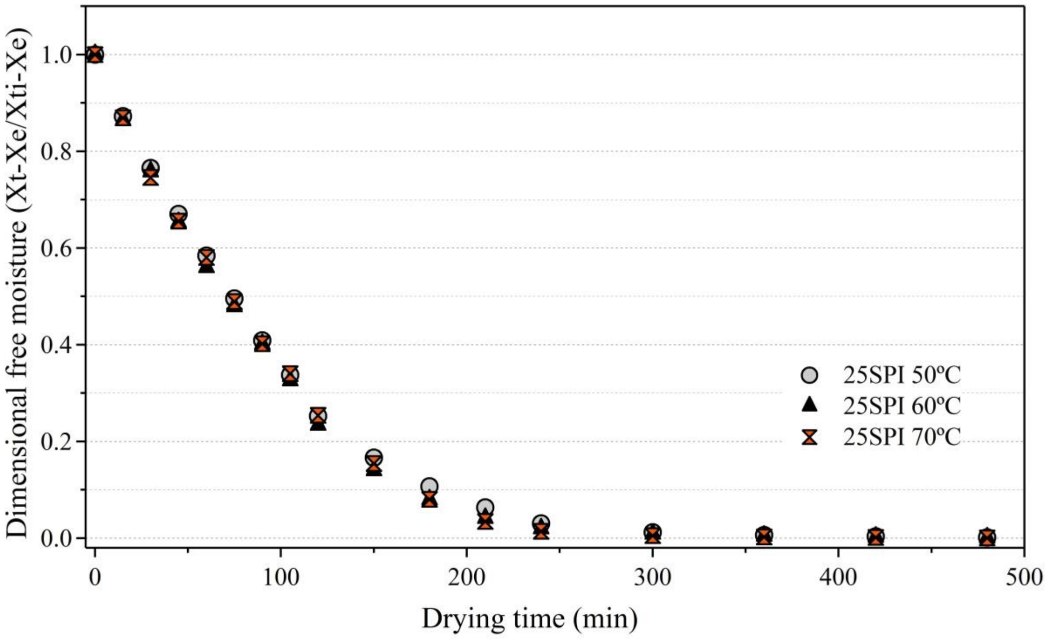

Figure 10. Effect of drying temperature for the sample containing 25% SPI.

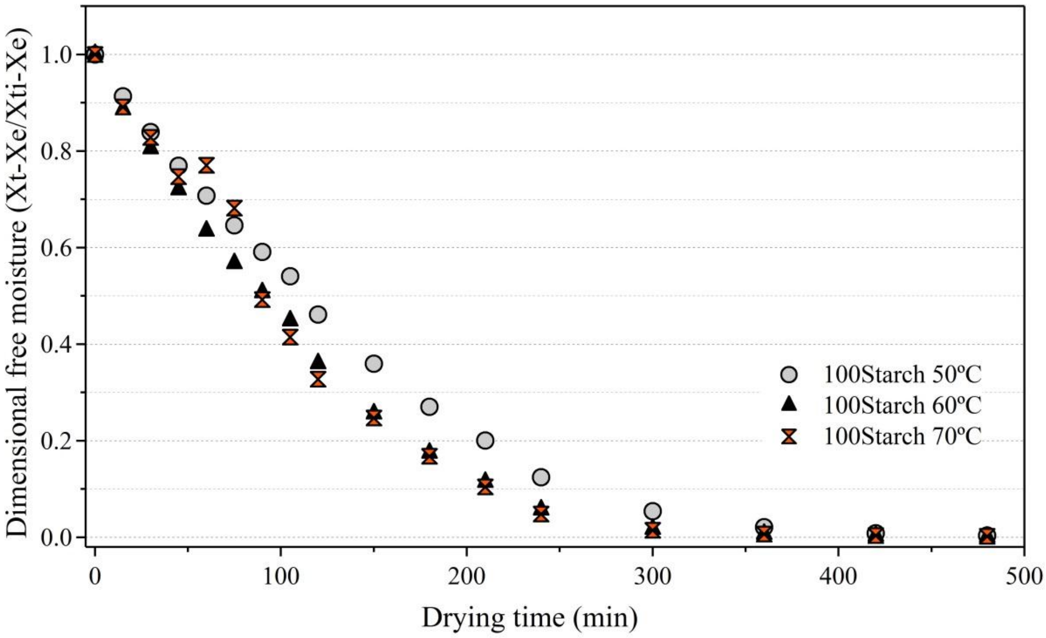

Figure 11. Effect of drying temperature for the sample containing 100% starch.

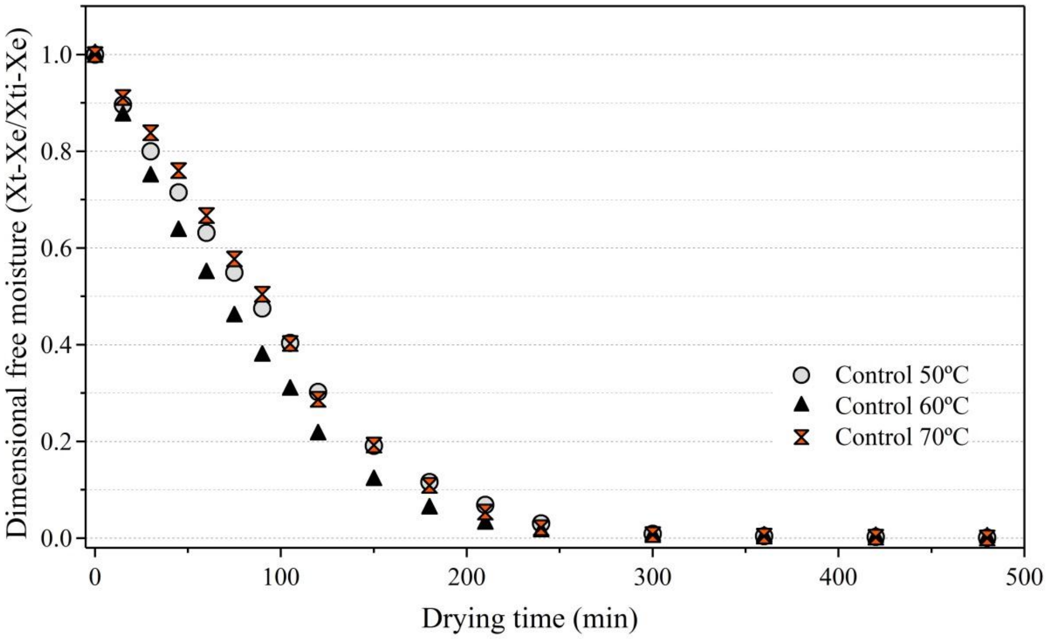

Figure 12. Effect of drying temperature on the control sample.

Effective diffusivity is a key parameter needed in the analysis, design and optimization of heat and mass transfer during food drying process [KHAN et al., 2017]. In our study, the Fick's model was fitted to experimental data by nonlinear regression analysis to determine the effective diffusivity (D_{ef}). The D_{ef} values showed to be dependent on the drying temperature (Table 9). According to Rizvi [1995], this coefficient is also dependent on material constituents. Lower moisture ratio trend to be found for the samples which present higher moisture diffusivity.

Table 9. Effective diffusivity values (D_{ef}) obtained for potatoes at different drying temperatures.

Samples	D_{ef}		
	50 °C	60 °C	70 °C
100% SPI	2.0252	2.6484	2.4937
75% SPI	2.1810	2.4926	2.6884
50% SPI	1.7137	2.4926	2.1810
25% SPI	2.0250	2.6484	2.3368
100% Starch	1.8694	2.3368	2.1810
Control	2.3368	2.6884	2.4926

Based on our results, the ideal drying time of coated potatoes is between 120-180 min, and the higher temperature and the lower SPI concentration should be considered.

CONCLUSION

The drying of potatoes with edible coatings may be performed by using a forced dryer. No constant drying rate period was observed. The drying curves presented a similar behavior in relation to those found in the literature. No significant effect of temperature on the drying curves was observed due to the high intrinsic moisture of potatoes and barrier properties provided by the coatings. The formation of a physical barrier by SPI-based hydrophobic coatings would reduce the water loss from potatoes, reducing the differences on drying profiles when the temperatures are changed from 50 to 70°C. The drying model of Midilli provided the best fit to the experimental data. Ideal time and temperature parameters for drying of the coatings at an industrial level may be achieved by using kinetic modeling. The type of food matrix and constituents of coatings seem to impact on drying parameters. Additional studies should be performed to confirm the benefits of coatings in reducing the oil absorption by French potatoes during the frying.

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