ARMANDO ABEL MASSINGUE

PROCESSING AND CHARACTERIZATION OF THE SURIMI-LIKE MATERIAL FROM MECHANICALLY DEBONED TURKEY MEAT

LAVRAS - MG

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Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Ciência dos Alimentos para obtenção do título de Doutor.

Orientador

Dr. Eduardo Mendes Ramos

LAVRAS – MG

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Ficha catalográfica elaborada pelo Sistema de Geração de Ficha Catalográfica da Biblioteca Universitária da UFLA, com dados informados pelo(a) próprio(a) autor(a).

Massingue, Armando Abel.
Processing and characterization of the surimi-like material from mechanically deboned turkey meat / Armando Abel Massingue. - 2018.
135 p.: il.

Orientador: Eduardo Mendes Ramos.
Tese (doutorado) – Universidade Federal de Lavras, 2018.
Bibliografia.

1. Mechanically deboned turkey meat. 2. Turkey surimi-like material. 3. Restructured cured and cooked broiler breast meat. I. Ramos, Eduardo Mendes. . II. Título.

ARMANDO ABEL MASSINGUE

PROCESSING AND CHARACTERIZATION OF THE SURIMI-LIKE MATERIAL FROM MECHANICALLY DEBONED TURKEY MEAT

OBTENÇÃO E CARACTERIZAÇÃO DE CONCENTRADOS PROTEICOS TIPO SURIMI A PARTIR DA CARNE MECANICAMENTE SEPARADA DE PERU

Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Ciência dos Alimentos para obtenção do título de Doutor.

APROVADA em 30 de Maio de 2018.

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LAVRAS – MG

2018

À minha esposa, Marta Massingue pela sua paciência e consentimento;
Aos meus filhos (Amélia, Abel, Carmone e Wilma)
que por esta causa seguiram a vida sem pai presente.
Aos meus pais (Abel e Catarina) por todo coração.

Dedico.

AGRADECIMENTOS

A Deus, pela vida, pela saúde, pelas oportunidades concedidas e pela força para trilhar nas dificuldades.

À Universidade Eduardo Mondlane pela oportunidade da minha formação profissional.

À Universidade Federal de Lavras, em especial, ao Departamento de Ciência dos Alimentos, pela oportunidade da minha formação acadêmica.

Ao Programa Estudantes-Convênio da Pós-Graduação (PEC-PG) e a Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) pela concessão da bolsa, sem ela teria sido impossível.

Ao Conselho Nacional de Ciência e Tecnologia (CNPq) e à Fundação para a Pesquisa do Estado de Minas Gerais (FAPEMIG) pelo financiamento do projeto.

Aos professores Eduardo Mendes Ramos, meu orientador, e Alcinéia de Souza Lemos Ramos, pela orientação e extrema dedicação e acompanhamento do trabalho, pela disponibilidade e generosidade reveladas ao longo destes anos de trabalho. Agradeço sinceramente.

Ao Professor Jaime Vilela Resende (Coordenador do curso de Pós-Graduação em Ciência dos Alimentos), pela valiosa carta de aceitação para a realização do doutorado em Ciência dos Alimentos na Universidade Federal de Lavras.

À professora Cristina Delarete Drummond (DS/UFLA) e ao técnico Isaac Filipe Moreira Konig (DMV/UFLA), pelo inestimável apoio na preparação e elaboração das análises histológicas, pela disponibilidade sempre manifestada e pela amizade.

Aos professores Alcinéia de Souza Lemos Ramos, Maria Emília de Sousa Gomes, Vanessa Riani Olmi Silva e Robledo de Almeida Torres Filho, pela participação na banca de defesa de tese, pelas contribuições e sugestões relevantes ao trabalho.

Aos colegas do laboratório de carnes: Ana Paula, Gabriela, Douglas, Amanda, Mariele, Sâmia, Lectícia, Greicy, Hewerton, Lucas, Luana, Angélica, Lívia e Maria Victória pelo tempo de

amizade e diversão no laboratório. E, pela simpatia com a minha esposa na sua visita ao Brasil, os jantares em família LabCarnes ... Vai a Minha Gratidão!

Aos meus pais, Catarina e Abel, por sempre terem me apoiado incondicionalmente. Deus abençoe muito a vocês!

A minha esposa, Martinha, pelo amor, carinho e paciência comigo; por sempre ter sido meu ombro amigo e com quem sempre pude contar e confiar. Sem você a vida não faria sentido. Amo muito você!

Aos meus filhos Amélia, Wilma, Abel e Carmone, pela compreensão e ternura sempre manifestadas. Espero que o entusiasmo, seriedade e empenho que dedico ao trabalho lhes possa servir de estímulo para fazerem sempre "mais e melhor".

Vão os meus agradecimentos aos professores João de Deus, Cleiton Nunes, Daniel Furtado, Ana Carla, Joelma Pereira, Roberta Hilsdorf, Roney Rocha, Roberto Batista e Luís Ronaldo Abreu por sua amizade e ensinamentos.

Meus agradecimentos se estendem a todos os professores e técnicos do DCA por proporcionar um ambiente de trabalho com amizade. Aprendi muito de vocês.

Também aprecio a gentileza da Eloá Lourenço do Carmo por sua grande ajuda no laboratório de Microscopia Eletrônica de Varredura, Michelle Gonçalves e Heloisa Martins por sua grande ajuda nas análises microbiológicas, e Isaac por ajuda no laboratório de citologia e histologia.

A todos os profissionais da UFLA que de alguma forma contribuíram para o desenvolvimento deste trabalho, em especial, as laboratoristas Ana Alice, Felipe Haddad (Tite), Constantina Torres (Tina), Creusa Rezende e Eliane Alcântra agradeço pela disponibilidade manifestada e pelo incansável acompanhamento nas análises.

A todos que de alguma forma contribuíram para que este sonho se tornasse realidade.

“Uma viagem de mil de milhas começa com um único passo”.

(Lao-Tsé)

ABSTRACT

The objective of this study was to process and characterize surimi-like material (SLM) from mechanically deboned turkey meat (MDTM) by washing with different solutions: water, 0.086M Sodium chloride, 0.060M Sodium bicarbonate, and 0.040M Potassium phosphate buffer (pH 6.8) in one, two or three cycles. The samples of surimi-like were evaluated for their quality characteristics and thermal gelling ability, which was tested with or without salt addition on cooking loss and texture profile of the gels. Selected gel was used in two proportions (30 and 60%, treatments TSL30 and TSL60, respectively) for an additional experiment conducted to evaluate the effect of the TSL addition as mechanically deboned turkey meat (MDTM) substitute on technological and sensory properties of the ready-to-eat restructured broiler breast (like "*Blanquet*"), compared to that made from 30% MDTM and control with 100% broiler breast (CONT). Washing significantly reduced fat content and increased moisture content ($P < 0.05$), but did not affect protein content in surimi. Increases in lightness values (L^*) and whiteness were observed in all treatments, except for those obtained by water washing that remained darker. Washing with sodium bicarbonate ($NaHCO_3$) removed mainly heme pigments and increased both pH values and water holding capacity. However, for all treatments, the cooking loss reduced and the texture profile improved ($P<0.05$) due to the addition of 2% salt (NaCl). Thus, $NaHCO_3$ washed samples were the good ones with the lowest cooking loss ($P<0.05$) and soft texture achieved in two washes. Hereinafter, $NaHCO_3$ SLM washed in two cycles was used in a meat product due to its desirable properties. The addition of 60% TSLM increased ($P<0.05$) the moisture and sodium contents, syneresis, water activity and pH values, and decreased the protein content. Treatments increased ($P<0.05$) the hardness, cohesiveness, springiness, and chewiness values due to the addition of MDTM or TSL; however, the adhesiveness did not change due to the treatments. Samples with MDTM were redder (high a^* values) and with TSL becoming yellower (higher h^* values) than control ($P<0.05$), while the b^* and C^* increased during storage time in all treatments. The incorporation of at least 30% SLM allow getting a similar product to that produced with whole broiler breast meat since it seems to retain the typical light color and soft flavor of poultry meat according to the sensory analysis.

Keywords: Mechanically deboned turkey meat; Turkey surimi-like material; Restructured cured and cooked broiler breast meat; Instrumental texture and color; Sensory evaluation.

RESUMO

No presente trabalho objetivou-se obter e caracterizar concentrados proteicos tipo surimi a partir da carne mecanicamente separada (CMS) de peru por lavagem com diferentes soluções: água, 0.086M cloreto de sódio, 0.060M bicarbonato de sódio e 0,040M tampão fosfato de potássio (pH 6,8) em um, dois ou três ciclos. Os produtos obtidos foram avaliados quanto as suas características de qualidade e capacidade de gelificação térmica, sendo testados com efeito de adição de sal na avaliar a redução de perdas por cozimento e melhoria da textura dos geis. O melhor gel foi utilizado em duas proporções (30 e 60%, respectivamente) num experimento adicional conduzido para avaliar o efeito da adição de surimi como substituto da CMS nas propriedades tecnológicas e sensoriais de um embutido de peito de frango (tipo "*Blanquet*"), sendo formulados também com 30% de CMS (MDTM) e controle (CONT) com 100% carne de peito. Do primeiro experimento observou-se que a lavagem reduziu significativamente o teor de gordura e aumentou o conteudo de umidade ($P<0,05$), mas não afetou o teor de proteína nos surimi. O aumento nos valores de luminosidade (L^*) e brancura foi observado em todos os tratamentos, com exceção dos obtidos por lavagem com água que permaneceram escuras. A lavagem com bicarbonato de sódio ($NaHCO_3$) removeu mais pigmentos heme e resultouem produtos com altos valores de pH e de capacidade de retenção de água. No entanto, para todos os tratamentos observou-se uma redução das perdas por cozimento e melhoria do perfil de textura ($P<0,05$) devido a adição de 2% de sal, mas os géis obtidos com $NaHCO_3$ foram os que tiveram valores mais baixos de perda por cozimento ($P<0,05$) em comparação com outras amostras, mesmo quando obtidas por apenas dois ciclos de lavagem. Assim, amostras de surimi obtidas com $NaHCO_3$ em duas lavagens foram aplicadas no embutido. Verificou-se que a adição de 60% de surimi aumentou ($P<0,05$) a umidade, o teor de sódio, a sinérese, a atividade de água e os valores de pH, e diminuiu o teor de proteína. Os tratamentos aumentaram ($P<0,05$) os valores de dureza, coesividade, flexibilidade e mastigabilidade devido à adição de CMS ou surimi; enquanto que a adesividade das amostras não diferiu significativamente. As amostras com CMS foram mais escuras (altos valores de a^*) e as com surimi tornaram-se mais amareladas (altos valores de $h°$) comparadas ao controle (100% peito de frango, $P<0,05$), enquanto b^* e C^* aumentaram durante o armazenamento em todos os tratamentos. Concluiu-se que a incorporação de pelo menos 30% de surimi permite obter um produto semelhante ao produzido com peito de frango inteiro, uma vez que parece manter a cor clara e o sabor suave típicos da carne de frango conforme resultados da avaliação sensorial.

Palavras-chave: Carne mecanicamente separada; Produto tipo-surimi; Embutido de peito de frango; Perfil de textura e cor; Avaliação sensorial.

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PART ONE

1. INTRODUCTION

The production of poultry meat plays an important role in the Brazilian economy. Since the poultry meat, especially the broiler meat is relatively cheaper, more nutritive and easier to prepare than other meat sources, such as beef and pork, and it composes the greatest option for the Brazilian consumers. In addition, Brazil has been ranked as the second largest producer of animal protein in the world which is a result of the management efficiency of the farms which employs genetic enhancement technology. Beside domestic market, Brazilian poultry meat is consumed by at least 150 nations, making the country the largest exporter of poultry since 2004. Data from the Brazilian Animal Protein Association (ABPA, 2015) indicate that in 2014, Brazil had 49 million chickens and meat production reached 12.9 million tons destined for domestic consumption and exports.

According to the Food and Agriculture Organization for the United Nations (FAO, 2017), in 2016, Brazil was ranked the second largest producer of turkey meat (9.8%) in the world. However, there are few official data concerning turkey slaughter into the country but frequently has been found in the domestic markets turkey meat cut-ups sold in different conditions, such as frozen seasoned thigh and frozen turkey breast. Lately, as well known, turkey slaughter is most expressive at the end of the years in which the turkey meat become most needed in special party days, such as Thanksgiving and Christmas. Elsewhere, all production chain generates inside meat cut-ups considerable byproduct portions that are rich in nutritive components, like protein and vitamins. Thus, by-products with low commercial value could be used in the meat industry to manufacture other products that can provide an extra income by the elimination problems of industrial sanitation. In the case of poultry (chicken and turkey), the technology of mechanically deboned meat (MDM) or mechanically separated meat (MSM) production allow obtaining meat ingredient largely exploited in comminuted meat products.

Though the application of the MDM in meat products presents a feasible way due to its past form, there are still certain problems concerning appearance and preservation. The main problem relates to high content in heme pigments and unsaturated fatty acids, and phospholipids from the bone marrow which promotes dull changes in color and perceived rancid flavor (off-flavor) due to the oxidative reactions.

Therefore, an alternative way for reducing these problems can be the production of surimi-like materials. The production of these products is similar to surimi, which is obtained by repeated water-washings to achieve the concentrated myofibrillar protein from mechanically separated fish flesh and also the addition of cryoprotectants compounds to prevent the protein denaturation during frozen storage. The main advantage for MDM surimi-like production could be its tasteless and odorless, and good technology properties: high water holding capacity and high gelling ability.

Recently, can be found researches reporting processing surimi-like materials from a different meat source, such as chicken and duck meat and their characterization. But, there are still scared published data reporting the use of the MDM from turkey for surimi-like production, its characterization and further application as a food ingredient. Thus, the goal of this study was to obtain and evaluate a surimi-like material from turkey mechanically deboned meat as a byproduct of the poultry industry by the conventional technique using different washing media.

2. REVIEW OF THE LITERATURE

2.1. Turkey meat

Turkey is the common name given to *Galliform* birds of the genus *Meleagris*. This genus contains the wild and domestic specimens and is native to the Americans. The turkeys belong to the Phylum: Chordata; Class: Avis; Order: Galliformes; Family: Meleagrididae; Genus: Meleagris; Species: *M. gallopavo* and *M. ocellata* (COSTA, 2006). Turkey (*Meleagris gallopavo*) is a domesticated version of wild turkey fowl adapted to commercial meat production. In addition, turkeys are one of the leanest types of poultry and a good source of protein and minerals such as sodium, potassium, and iron (FERREIRA et al., 2000).

There are a few reports on the characterization of turkey meat. However, turkeys were at one time mainly consumed on special occasions, such as Christmas (in the United Kingdom and Brazil) or Thanksgiving (in the United States). It is especially appreciated due to its tenderness and taste. Thereafter, they markedly increase and are becoming part of the everyday diet in many parts of the world. High dietetic value is mainly due to its high protein and low-fat content. In addition to the high protein level up to 20.3-26.7%, fat content of breast and thigh meats below 2%, turkey meat is also outlined with high mineral content by around of 1.17– 1.32% (OBLAKOVA et al., 2016).

In turkeys, the chemical composition (%) of animal carcasses changes from birth to market maturity (DIKEMAN; DAVINE, 2014): moisture (from 73.0 to 60.0), crude protein (23.6 to 21.2), fat (2.8 to 17.6) and ash (0.6 to 1.3), respectively. The myoglobin concentration also changes from 0.4 to 1.5 mg per gram of tissue depending on maturity stage.

The turkey meat is an excellent raw material for industrialization. Moreover, its healthy value has been recognized by consumers. An important data for the domestic market were that turkey products overcome the seasonal consumption. Today, its supply and demand are stable during the year because there is an increase of the industrialization of attractive and practical products such as lasagna, pâtés, and pizzas (MENDES; SALDANHA, 2004).

The quality of turkey meat has been highly influenced by different factors, but the most reduced quality is attributed to a delayed chilling which leads to a rapid postmortem pH fall.

Thereafter, improper slow chilling of turkey pectoral muscle causes accelerated postmortem glycolysis while the carcass temperature is still high, resulting in protein denaturation and poor meat quality (PSE-like). PSE meat phenomenon is often observed in poultry, particularly in turkey breast muscles (DIKEMAN; DAVINE, 2014). When it occurs, the resulted meat is unsuitable for directly putting on consumption market. However, it may be utilized for meat by-product processing.

Nevertheless, if the turkey is ground, it commonly results in a mixture of dark and light meat, including adhering skin and visible fat. These differences in the amounts of these components used by individual processors to prepare the ground turkey would affect the levels of lipids observed in the final product (WONG; SAMPUGNA; DICKEY, 1993).

2.2. Turkey meat production

The most common sources of meat are domesticated animal species such as cattle, pigs, and poultry and to lesser extent buffaloes, sheep and goats. During the last few years, Brazilian poultry production has developed with broiler genetic improvement. Its live performance results are among the best in the world as a result of modern technologies applied in rearing management, nutrition, housing and health control (PATRICIO et al., 2012).

Poultry is the second most widely eaten type of meat globally, accounting for 35.0% of total meat production worldwide compared to pork at 36.0% (FAO, 2014). And, among poultry meats, turkeys get a great feature in the meat supply. According to FAO (2017), more than 450 million heads of turkeys have raised annually for consumption since 2012. Global turkey meat production in 2012 was approximately 7.4 million tons. However, in 2016 the production dropped to 6.1 million tons, with the main producers accounting more than 50.0% of the production of turkey meat in the world. Ordered by its importance, the United States (44.7%), Brazil (9.8%), Germany (8.0%), France (6.5%), and Italy (5.5%) were the five largest world producers of turkey meat. Brazil is ranked the second highest country that produced turkey meat with 596,300 ton in 2016. It shows that the turkey production is stable and increases in this country. For example, production share has reached approximately 200.6% of population growth since 2004 (FAO, 2017).

During the last 5-years (2012 – 2016), the Brazilian turkey meat production mean has ranged at 515 thousand tons, but the per capita consumption remains at approximately 1.7 kg per year, lower than that from European countries (ABPA, 2016). Despite the lower availability of turkey meat in the domestic market, more than 30% of Brazilian turkey meat is annually sold in international markets as whole carcass and/or parts with added value (ABPA, 2016). The most important importers of turkey meat are (in 2014): Mexico, China, and European Union.

It seems that turkey share population is lower, but if were taken in consideration its carcass weight, which represents a high carcass yield, could be suitable to affirm that turkey has many benefits compared to chicken (RIBARSKI; OBLAKOVA, 2016). On the other hand, the demand for high pricing of turkey meat cut-up parts promotes the agribusiness associated with the high marketing value. Thus, this overcomes opened the door for by-products production, which impairs to chicken by-products leads the various meat processing products, and serve as low-cost meat protein supply worldwide (MILLER, 1968; KAYGISIZ; CEVGER, 2010).

2.3. Meat proteins

The muscle tissue is composed of 15-22% of proteins, 1-13% of fat, 75-85% of moisture, and 1.5% non-protein nitrogenized substances, 1% of carbohydrates and 1% of ash contents (PARDI et al., 1995). However, the chemical composition of the muscle tissue can vary as affected by different factors, such as genetic conditions (specie, breed), sex, age, cut type of muscle, etc. (GOMIDE; RAMOS; FONTES, 2013).

Proteins, the most important functional components in muscle, confer of the desirable physicochemical and sensory attributes of muscle foods. The functionality of proteins in food processing refers to any property of the protein that affects palatability to the final product, and it should be distinguished from the functionality of proteins in living tissues (DAMODARAN; PARAF, 1997). The muscle proteins are divided into myofibrillar, sarcoplasmic and stroma proteins.

The myofibrillar proteins compose about 52-56%, whereas sarcoplasmic and stroma proteins are around of 30-35% and 10-15% of the total protein weight, respectively (SGARBIERI, 1996). Myofibrillar proteins are made up of major proteins, such as myosin, actin,

tropomyosin, troponin and actinin, which are functional proteins, responsible for the conformational structure and eating quality of meat and meat products (BABJI; GNA, 1994).

The myosin and actin myofibrils form the highly organized patterns of the contractile muscle fibers. Each of these two protein systems gives toughness contributions that respond to a number of different physical factors. Sarcoplasmic proteins that are mostly water-soluble glycolytic enzymes and pigments are less viscous with lower water holding capacity (WHC) and their molecular weights range at 20,000-100,000 Dalton. Moreover, stromatic proteins are insoluble in water and aqueous salt solution and compose the connective tissue. It consists mainly of the protein collagen (approximately 5% of total protein weight, depending on muscle type), which is slightly different in forms and it exists in the muscle in strong and dense structures ranging from microscopic endomysium sheets surrounding individual muscle fibers to massive tendons (MARTENS; STABURSVIK; MARTENS, 1982).

The proteins structure stability is maintained by various cross-linked binds and chemical interactions among different groups of amino acids that form a determined protein. At pH values above and below the isoelectric point (pH 3.5-6.5), more water interacts with the protein charges. Net charges and charge repulsion contribute to greater protein solubility and exposing more hydrophobic groups. Unfolding (denaturation) at low or high pH values occurs because of a decrease in electrostatic bonds (HALL, 1996).

The temperature of the media is another factor affecting protein solubility. When it range from 40-45^{o}C become optimal for solubilizing of major proteins, and protein denaturation occurs when the high-temperature values are achieved (RAMOS; GOMIDE, 2017). This process is always accompanied by the reduction of its solubility and texture profile changes. However, relating heat denaturation of muscle proteins to texture changes in heat-treated meat there are some uncertainty and confusion still appear to exist with regard to the denaturation temperatures of the different important proteins, as well as to their texture roles (MARTENS; STABURSVIK; MARTENS, 1982).

2.4. Poultry meat by-products

Broilers, chickens, laying hens, and turkeys comprise the major sources of poultry raw materials. However, they all yield similar final rendered products. Ducks and other less dominant avian species may show some variations (DIKEMAN; DAVINE, 2014).

The quantity-qualitative potential of raw meat materials that are suitable for the manufacture as by-products varies widely between economic classes and regions throughout the world. The terms by-product is basically used to denote the parts which are not included in the primary product (JAYATHILAKAN et al., 2012).

Since further processed turkey and chicken products have grown, more parts have become available for mechanical separation. Chicken broilers are now routinely cut-up, or hand deboned. After cut-up or hand-deboning the frame, back, neck, drumsticks, and wings are often mechanically separated to be used in various further-processed meat products. Turkeys are also now sold as cut-up parts. More commonly, turkeys are hand-deboned and further processed. After hand-deboning of turkey carcasses, its by-products processing are also mechanically separated providing a new raw material for processed meat products: mechanically deboned meat (OWENS; ALVARADO; SAMS, 2010).

2.5. Mechanically deboned meat

Mechanically deboned meat (MDM) or mechanically separated meat are generic terms used to describe residual meat which has been recovered or separated using mechanical equipment from animal bones or poultry carcasses from which the bulk of the meat has been previously manually removed (SERDAROGLU et al., 2005).

Mechanical deboning involves grinding meat and bone together and forcing the mix through a fine screen or slotted surface to remove bone particles. This permits the recovery of most of the residual meat, which would otherwise be difficult or uneconomical to acquire. The resultant MDM has the appearance of finally comminuted meat (SERDAROGLU et al., 2005).

MDM is a widely used raw material for the production of emulsified meat products, such as sausages (MASSINGUE et al., 2018; PEREIRA et al., 2011, 2016; JAYATHILAKAN et al.,

2012). Its application in the formulation of the emulsified meat products is due to its paste form and relatively low cost. The technology of mechanically deboned poultry meat production emerged in the United States at the end of the decade of 50, and lately became largely explored in Brazil since the decade of the 1990s as driven by the raised production of poultry meat and in order to satisfy consumer preferences for chicken cuts and fillets instead of whole chickens, thus giving rise to finding ways to take advantage of chicken backs, necks and bones from deboning techniques (DIKEMAN; DIVINE, 2014). These techniques salvage a lot of soft, edible, highly nutritious meat that does not contain connective tissue that would otherwise essentially be wasted. As the world population grows we cannot afford to discard nutritious products that can be salvaged (DIKEMAN; DIVINE, 2014).

The mechanical deboning process has branched out mainly due to its simplicity to obtain and process industrialized products, and then it is an efficient method of harvesting meat from parts left after hand deboning. These poor quality poultry by-products that cannot be consumed directly consist of 40% of the whole carcass (SÖZEN; HECER, 2013).

Many differences have been documented for various types of mechanically deboned meat such as color stability, mineral and vitamin content, cholesterol content and lipid oxidation (SERDAROGLU et al., 2005). As a result of the inclusion of bone marrow in MDM, there is a greater variation in the fatty acid content and a higher percentage of cholesterol and phospholipid in MDM (SERDAROGLU et al., 2005). However, quality characteristics for MDM are established by the Brazilian legislation (BRAZIL, 2000), as that the protein (minimum of 12%), total fat (maximum of 30%) and calcium content (maximum 1.5%, in dry matter basis), and peroxide index within the limit of 1 mEq of KOH per kilogram of fat.

Several studies evaluating the proximate composition of MDPM from different birds were done and featured for MDM from laying hens (HAM; YOUNG, 1983) and chicken (POLLONIO, 1994; PEREIRA et al., 2011), and had been shown to be quite close into legislation. MDPM composes of the low-cost and wholesome nutritive solution available in the marketing system. The availability of meat products containing MDPM is likely source of information that recently, the consumption of boneless poultry meat has increased (SÖZEN; HECER, 2013).

Regardless of how the MDM is labeled, it becomes much more vulnerable to both lipid oxidation and microbial change than its intact counterpart due to the breaking of cell walls and much greater total surface area of the small particles. Due to these changes that can reduce its

lifespan and of the product in which was used as an ingredient, the current regulation recommends that shelf-life of MDPM is of 24 hours at a temperature below 4°C, 3 days if kept at 0°C, and 90 days if stored at a temperature of -18°C (BRAZIL, 2000).

Although frozen storage prevents many undesirable changes in meat, some oxidative reactions which adversely affect product quality, still occur (PETTERSEN et al., 2004). The peroxidation of lipids is an extensive economic problem for the meat industry because it leads to the development of unpleasant "rancid" or "off" flavors as well potentially toxic end products (HALLIWELL et al., 1995). In the poultry industry, this problem has shown different concerns even in whole carcasses. For example, chicken has less of a tendency to develop off-flavors than turkey due to the higher level of the antioxidant vitamin E in chicken (DIKEMAN; DAVINE, 2014). As known, myoglobin, and hemoglobin are main sarcoplasmic proteins. Since they contain iron in its composition, they are main correlated with the sensorial color of meats. Chickens and, to some extent, turkeys display the largest differences in muscle color known to occur in one single animal. Breast muscle approaches the whiteness of some fish species, while leg meat is comparable to pork and sometimes beef in redness (SCHREURS et al., 2000).

Several studies mentioned by PETTERSEN et al. (2004) that point to the major strategies for preventing oxidation in MDPM with the use of free radical terminators, such as phenolic antioxidants and preservatives to restrict the access of light and oxygen during both processing and storage steps, but is largely known that this practice is not allowed by the Brazilian current law (BRAZIL, 2000). Therefore, an innovative alternative to reduce these problems and largely reported as suitable in the improvement of mechanically deboned meat is concerning of washing procedure which allows removing blood, myoglobin, hemoglobin, fat and other undesirable substances generating a surimi-like product with remarkable physicochemical properties.

2.6. Surimi and surimi-like material processing

2.6.1. Surimi

Surimi is defined as a wet protein concentrate made of fish muscle that is obtained from mechanically deboned fish flesh that is processed through mincing, washing, mixing with

cryoprotectant, and freezing (YASOTHAI; GIRIPRASAD, 2015). It is not itself a foodstuff (SONU, 1986). This product had its origin in Japan, around the XVII century (years of 1115), where it is commonly used as an important food ingredient (PARK, 2014). Then, surimi is a Japanese term for mechanically deboned fish flesh which has been washed with water to remove sarcoplasmic proteins and mixed with cryoprotectants agents for a good frozen shelf life (PARK, 2014).

The cryoprotectants additives, compounds such sucrose, sorbitol, polydextrose, sodium tripolyphosphate, sodium bicarbonate, sodium nitrite, and others, give the surimi the ability to resist protein denaturation during subsequent frozen storage (SONU, 1986; PARK, 2014).

The definition of surimi was also recently adopted by Brazilian regulation relative to the quality of meat and meat products (BRAZIL, 2017). The leaching meat residue (surimi) is a tasteless and odorless meat product which possesses a high water holding capacity and gelling ability (CORTEZ-VEGA et al., 2014), but it became most popular due to its unique textural properties as well as high nutritional value (PARK, 2014). Since the beginning of the 1980s, enormous interest in surimi has been generated among the seafood and other food industrial enterprises because of the rapid growth in the popularity of surimi-based products. This network gained more stability when the Japanese researchers discovered the functional properties of cryoprotectants in protecting surimi during frozen storage. Frozen storage brought challenges in surimi marketing. Although the effect of cryoprotectants during frozen storage of surimi could vary, it was markedly efficient to preserve its biochemical and functional properties (SHARMA, 2005).

Alaska pollock (*Theragra chalcogrammus*) was the most widely utilized species in the Japanese surimi industry because of its abundance, good gel-forming capability, year-round availability, white flesh, and reasonable price (SONU, 2002).

However, a decrease in Alaska pollock harvests, from over 6.5 million metric tons in the late 1980s to less than 3 million metric tons since the year 2000, has opened the door for the utilization of new species in the surimi industry (PARK, 2014; TINA et al., 2010). The producers had early turned their attention to other resources, such as polar cod, Pacific whiting, yellow croaker, hoki, white croaker, threadfin bream, Chilean mackerels, arrowtooth flounder, blue whiting, menhaden, bigeye snapper, threadfin bream, lizardfish, and tilapia (SONU, 2002; TINA et al., 2010).

Thereafter, a variety of products such as imitation crab meat, kamaboko, flavored kamaboko, chikuwa, satsumiage, hanpen, and fish sausage in which the surimi is served as a potential raw material (TINA et al., 2010). Nowadays, and even with the introduction of these new species of fish for surimi production, the international marketplace for surimi did not seem to improve as well. It was still noted a continued decline in Japanese consumption of surimi seafood during the 1990s and early 2000s as the younger generations are gradually shifting to a more Western and meat diet (SONU, 2002). This shift has been partly offset by an increasing market for surimi-based products in Europe, Russia, and Southeast Asia, and these new markets are more open to different sources of raw materials and new methods of processing. The surimi processing and the usual techniques for quality of surimi production could be influenced by several conditions (PARK, 2014).

Decanter technology and new washing techniques have allowed the processing of surimi from fatty fish such as mackerel (PARK, 2014). These techniques were seen to be used for surimi-like processing, like a surimi imitation product, from different animals meat sources than fish, such as pork, beef, and poultry meat.

2.6.2. Surimi-like material

The scarcity of Alaska pollock as surimi raw material has brought a new trend in surimi manufacture. New sources for surimi are obtained from other new species than fish. However, when obtained from other types of muscle (that is, not fish), the protein concentrate is known as Surimi-like material (YASOTHAI; GIRIPRASAD, 2015), which present functional properties that makes it suitable as functional meat (XIONG, HO; SHAHIDI, 1999; TINA et al., 2010).

Currently, there are several researches worldwide pointing to obtain a surimi-like material (as surimi imitation) utilizing both white or red meat sources from different animals, such as beef and pork (JIN et al., 2009), lambs or sheep (McCORMICK et al., 1993; ANTONOMANOLAKI et al., 1999), laying hens (NOWSAD et al., 2000a, 2000b) and spent duck meat (NG; HUDA, 2011; ISMAIL et al. 2014), and either by-products: mechanically deboned meat from chicken (BADJI et al., 1995; MIN; LEE, 2004), or from turkey (HERNANDEZ et al., 1986; ELKALIFA et al.,1988), and beef hearts (McKEITH et al., 1988; DESMOND; KENNY, 1998), beef head meat and tongue (McKEITH et al., 1988). The surimi-like production technology has been

reported as suitable to add value to meat industry by-products (ISMAIL et al., 2011; CORTEZ-VEGA et al., 2012).

Since the high-fat content of red meat, high of collagen and heme pigment concentrations can cause several problems when the red meat is used to produce surimi-like material (PARK et al., 1996; ANTONOMANOLAKI et al., 1999), poultry can represent itself a great potential source of surimi-like material due to the white fibers. Additionally, poultry meat production increases and its meat are accessible for the low-income people. This meat consumption outcome is ascribed to the high amount of low valued parts that are used to produce the mechanically deboned poultry meat.

The MDPM is good raw meat material with 13% to 15% of meat proteins (HRYNETS et al., 2010). Thus, it is allowed to be used as the meat substitute in several meat products. Since the mechanical deboning process results in the release of a considerable amount of fat and bone particles, the utilization of MDPM is limited by the legislation (BRAZIL, 2000). The darker color is another problem with MDPM, due to the release of a substantial quantity of hemoglobin from bone marrow during mechanical deboning (SERDAROGLU et al., 2005). In addition, hemoglobin presents significant color problems because it is easily oxidized and is highly susceptible to heat denaturation during processing and storage. During the separation process, the meat is exposed to considerable air, which may accelerate the oxidation of heme pigments. This phenomenon is strictly linked to lipid oxidation, which, together with color instability, is the major problem with mechanically separated poultry (DAWSON; GARTNER, 1983).

In that way, the process used for the production of surimi-like material allow removing fat, pigments, sarcoplasmic proteins, and inorganic salts. A large number of muscle proteinases are also removed during the washing process in surimi production, resulting in less activity in surimi (PARK, 2014). The production of surimi-like material from poultry meat represents a well come innovation in the poultry industry. However, the study of poultry surimi-like material is still mostly focused on chicken. There has been limited research concerning non-chicken poultry meat. In Brazil, turkey meat and its by-products as one of non-chicken poultry meat have a prospect to be used as a new source of surimi-like material.

2.6.3. Factors affecting the quality of surimi and surimi-like materials

The quality of surimi depends on several factors, as follows: washing media, number of washing cycles, meat and washing solution ratio, pH, time and temperature of processing (REINHEIMER; SCENNA; MUSSATI et al., 2016).

Washing is important to improve color because removes fat, blood, pigments, and water-soluble proteins from meat which results in an increase of myofibrillar protein especially actin and myosin ratio. Myosin is mainly responsible for gel formation. The washing media had also shown the marked effect on the drip and textural properties. Additionally, washing procedure increases the moisture content which plays important role in surimi and surimi-like products quality. The standard moisture is at least 78% in surimi (CORTEZ-VEGA, 2008).

Different washing solutions and washing cycles had been tested by various researchers to obtain surimi and surimi-like products. For example, water washing was used to obtain beef heart surimi (DESMOND; KENNY, 1988) and duck meat surimi (RAMADHAN et al., 2012); 0.5% sodium bicarbonate solution was used during the first and second washings, and 0.5% sodium chloride in the third washing to obtain the mechanically separated chicken surimi (CORTEZ-VEGA et al., 2014). Jin et al. (2009) had lately tested the water washing with pH adjustment procedure to obtain a surimi-like material from pork leg meat. While Hrynets et al. (2010) obtained protein concentrates from mechanically separated turkey meat by acidic and alkaline extraction methods. Beyond water, sodium chloride, sodium bicarbonate, and sodium phosphate buffer have been suggested as useful washing solutions for surimi-like material processing (RAMADHAN et al. 2014). Although the washing procedure is the key of surimi quality, the number of cycles and the ratio meat: washing solution could be also considered crucial on the myofibrillar protein concentrating and removing of fat and sarcoplasmic proteins. In this context, several researchers had been tested washings utilizing different ratios of meat: washing solution. For example, CORTEZ-VEGA et al. (2013) reported that ratios range from 1:2 and 1:4 are suitable to obtain a good processing yield, and high ratios (1:6) resulted in the lowest extraction yields. This behavior could be due to reported finds that washing results in loss of both sarcoplasmic and myofibrillar proteins. However, these concerns vary when water or salt solution or either alkali or acidic media are used (YANG; FRONING, 1992).

Repeated washings play important mean for the gel quality. The first washing removes mostly fat and heme pigments than subsequent washes. Therefore, the time and temperature have a significant influence on the amount of protein extracted during surimi processing. CORTEZ-VEGA et al. (2013) studying the optimal conditions for surimi-like material production utilizing mechanically deboned chicken meat as a meat source, they reported that the increase in washing time per cycle resulted in a negative effect on the protein content by overall diminishing protein content by washing with the increased time from 5 to 15 min. Firstly, protein content increased from 5 to 10 min and decreased from 10 to 15 min. On the other hand, they also observed a decrease in protein content with temperature in the range of 2–12°C. However, middle value (7°C) is the most adequate for the process. In general, in the lower temperature could be difficult to remove fat but the higher temperature is undesirable because high protein content becomes extracted.

The pH media act in a different way in protein solubility. The isoelectric point (pI), in which proteins have zero net charges in solution, results in minimum solubility and maximum precipitation, but it is very specific for different proteins (GEHRING et al., 2009). The protein solubilization can be accomplished with an alkaline pH of approximately 10.5 or higher and an acidic pH of approximately 3.5, however, the most proteins are least soluble at about pH 5.2 to 5.5 (PARK, 2014). TINA et al. (2011) reported that the acidic solubilization process yielded the highest protein recovery and the alkaline solubilization generated the highest lipid reduction, while the conventional surimi process yielded the lowest reduction. In addition, they observed that surimi-like material produced by the conventional method had the highest gel strength, salt extractable protein, and water holding capacity. The conventional surimi also had the highest cohesiveness, hardness, and gumminess values and the lowest springiness value. However, surimi-like material produced by the acidic and alkaline processes presented higher whiteness values but protein oxidation could be easily induced by extreme pH values.

On the other hand, if salt solutions were selected to be used for surimi processing might be made in consideration the optimal ionic strength in which will be suppressed avoided the high losses of salt-soluble proteins (LANIER; CARVAJAL; YONGSAWATDIGUL, 2005).

The cryoprotectants additives avoid protein denaturation during freezing storage. As well mentioned above, there are different kinds of these compounds. However, these substances are commonly used in combination in various proportions (w/w) into surimi. There are different

studies reporting the combinations of cryoprotectants additives into stability of surimi during freezing storage, such as: 4% sorbitol + 0.5% sodium tripolyphosphate in beef heart surimi (DESMOND; KENNY, 1988); 4% sucrose + 4% sorbitol + 0.2% sodium tripolyphosphate in mechanically separated chicken meat surimi (CORTEZ-VEGA et al., 2014); 6% mix (sucrose + sorbitol, ratio 1:1) + 6% polydextrose in duck meat surimi (RAMADHAN et al., 2012); 5% sorbitol + 4% sucrose + 0.3% Triphosphate + 0.4% sodium bicarbonate + 0.03% sodium nitrate in MDTM protein isolates processed by acidic and alkaline extractions (HRYNETS et al., 2010).

2.7. Surimi and surimi-like gelation

Surimi, like the muscle proteins of other animal species, forms thermo-irreversible gels upon heating, which do not melt with further temperature change. Then, surimi is known to produce gels of very high strength and deformability (PARK, 2014). For a good gelation, it is necessary to add salt to the surimi and raise its temperature. With the addition of salt, the myofibrillar proteins are solubilized, forming an actomyosin colloid as result of heat gelatinization (LANIER; CARVAJAL; YONGSAWATDIGUL, 2005; SUN; HOLLEY, 2011).

The gelation of the surimi and surimi-based products occurs as a result of heat-induced dissociation of the actin-myosin complex followed by the formation of covalent bonds between myosin chains. Gelation of actomyosin is, therefore, a form of myosin gelation where actin acts to enhance the gel-forming ability of myosin. Actin increases the rigidity of actomyosin gels maximally at a myosin: actin mole ratio of 1.5-2.0. Therefore, previous studies have reported that the ability of actin to increase the gel rigidity of myosin is dependent on the species of myosin (ZEIGLER; FOEGEDING, 1990). At pH 6.0**,** actin has a similar effect on increasing the rigidity of porcine cardiac actomyosin and rabbit skeletal actomyosin gels, but at the optimum pH for cardiac myosin gelation (pH 5.4)**,** there is no enhancement of rigidity (SAMEJIMA et al., 1988).

During gelation process of surimi in order to produce surimi-based gelled products, relatively high concentrations of NaCl (up to 3%) are added to the surimi to induce dissociation of the actomyosin, allowing the subsequent sol-gel transition to occur at room temperature. The gel is then stabilized by heating to induce the formation of limited amounts of actomyosin, which acts as a crosslinker between the 'tails' of the bound and free myosin molecules (OHSHIMA et

al., 1993). Gelation ability of surimi-like materials is largely dependent on the processing method and changes in the protein components (BABJI; GNA, 1994).

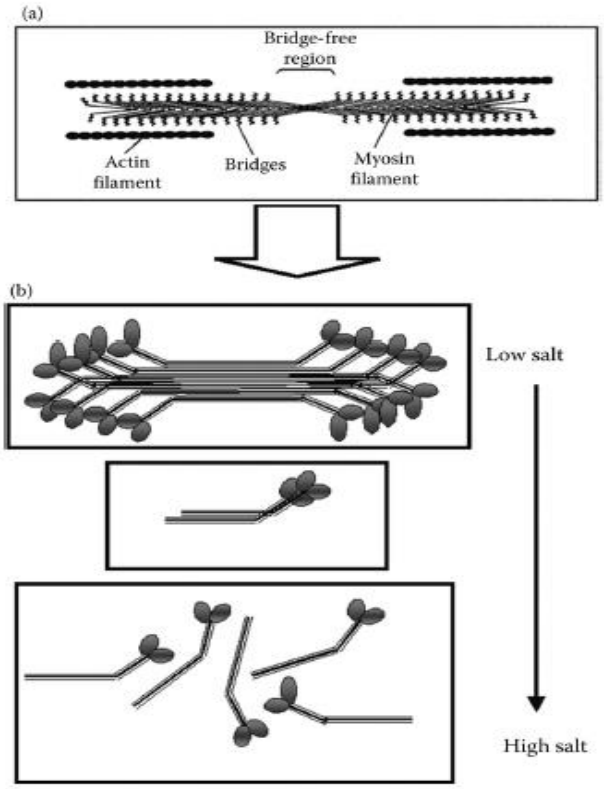
Gel-forming ability is one of the most important functional properties of meat proteins in which myofibrillar proteins play the most important role, and depends on both intrinsic and extrinsic factors, including meat source species, physicochemical properties of muscle proteins, the presence of endogenous enzymes such as proteinases and transglutaminase, and the conditions used in processing (CORTEZ-VEGA et al., 2013). Gelation is induced by the denaturation of protein and the subsequent aggregation of the denatured protein, which is reflected in the rheological properties (AHMAD et al. 2007). Thus, protein gels are considered as responsible for the basic texture of a wide variety of foods.

An improvement of surimi gel quality has been one of the major thrusts in surimi gel products. PARK et al. (1996) compared surimi-like material from beef, pork, and fish, and then observed that gel hardness increasing was in the order of fish, pork, and beef when gels were heated at a rate of 0.5^{o}C/min to an endpoint of 60°C. Overall, salt-added surimi becomes a viscous sol with the denaturation by heat treatment and an elastic gel with the aggregation by a further increase in temperature (AHMAD et al. 2007). During heating, a large number of hydrogen bonds that maintain the folded protein structure are broken between the carbonyl and amino groups in the peptide backbone, which become extensively hydrated. This hydration of exposed peptide backbones is thus a key factor in the water holding capacity of the gel that is subsequently formed by protein-protein aggregation (PARK, 2014).

Owing to explain how heating gelation occurs, there are the details of arrangements between actin and myosin in muscle, and its disassembly in solution as ionic strength is increased, is represented in Figure 2.1.

The myosin monomers have rod-like tails packaged end-to-end in a regular staggered array. The globular myosin heads project from either end, leaving a bare central region and form the cross bridges that interact with the thin filaments in intact myofibrils (Fig. 2.1a) during contraction. Myosin and actomyosin can be extracted by treatment with solutions of high ionic strength because this causes the thick filaments to depolymerize, leading to disassembly of the sarcomeres of the myofibrils (Fig. 2.1b).

Figure 2.1 - (a) Details of arrangements between thin filaments (actin) and thick filaments (myosin) in muscle. (b) Disassembly of thick filaments in solution as ionic strength is increased.

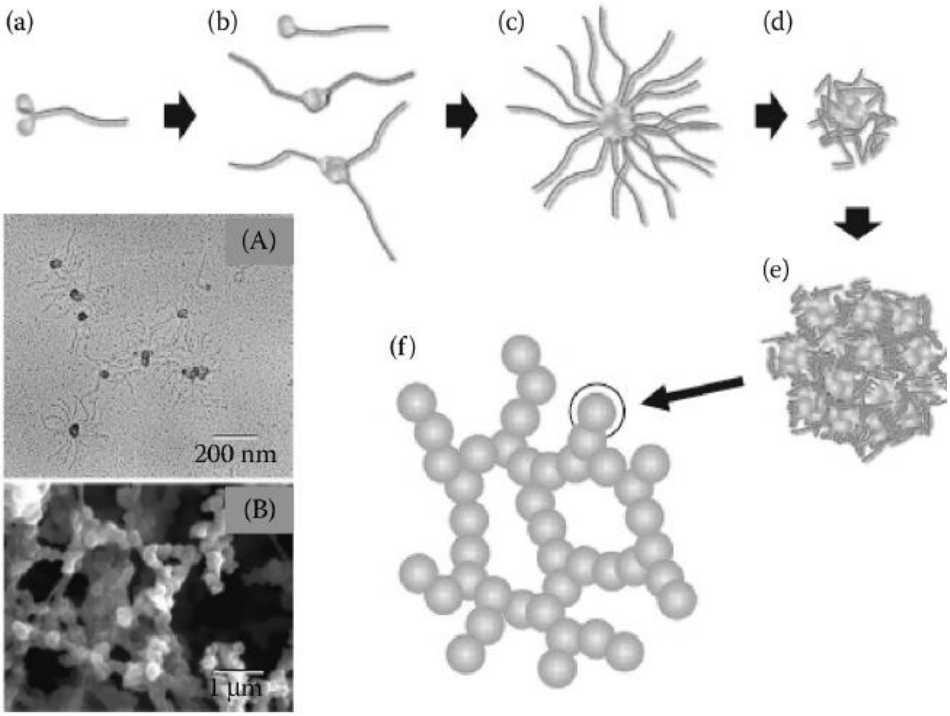


Source: PARK, 2014.

The salt, usually sodium or potassium chloride, facilitates solubilization of the myosin. Myosin and actin are soluble in mild salt (NaCl) solution (1–8%), but are largely insoluble in water of lower ionic strength (~0.05 to ~0.5%) (PARK, 2014).

In addition, is myosin that mainly contributes to gel formation and water holding in cooked comminuted meat products (FUKAZAWA et al., 1961a, b; MACFARLANE et al., 1977), and the heat-induced gel formation of myosin is schematized in Figure 2.2.

Figure 2.2 - Heat-induced gel formation of myosin monomer. (a) Unheated; (b) Cluster formation in early heating; (c) Daisy wheel formation of myosin head-to-head; (d) Denaturation of tail portions; (e) Clusters bound through denatured tails; and, (f) gel network formation. Photomicrographs: (A) Transmission electron microscope; and, (B) Field Emission Scanning microscope.



Source: PARK, 2014.

2.8. Surimi-like material as a food ingredient

According to the 2016 Food and Health Survey, approximately two-thirds of Americans are trying to consume more protein or as much as possible, up significantly from 54% in 2015 and 50% in 2014. One-fifth of Americans view plant protein as more healthful than they did the previous year, compared to 8% who see it as less healthful. Views of animal protein, however, were split, with 12% perceiving it as more healthful than the previous year and 15% perceiving it as less healthful (IFICF, 2017).

A typical sausage product contains as much as 30% fat. The amount of fat in meat products plays an important role in determining the sensorial and quality characteristics, including stabilizing emulsions and improving their water-holding capacity (WHC) (HUGHES; CONFRADES; TROY, 1997). Since a high-fat diet is a risk factor for obesity and cardiovascular diseases, among other health problems, more and more consumers demand low-fat or reduced-fat meat products (CORTEZ-VEGA et al., 2013a). However, many consumers believe that excessive consumption of meat and meat products is associated with obesity and various diseases due to their high-fat content (BIESALSKI, 2005). In this sense, the demand for healthier food products, especially low-fat products, is rapidly increasing, with new low- and reduced-fat meat products being developed (CIERACH et al., 2009), although the study of the association between meat consumption and the risk of developing cancer has produced inconsistent results, with some studies finding no association between dietary fat intake from meat products and colorectal cancer (FERGUSON, 2010).

However, reduction of the fat content of these products can be detrimental to their overall quality. The major problem of low-fat meat products is the resulting decline in palatability (KHALIL, 2000; SERDAROGLU, 2006). Other problems include reduced cooking yield, soft and mushy texture, and excessive purge in packages (KEETON, 1994). Thus, productions of low-fat meat products without loss of quality need to be achieved through the use of various technologies and ingredients such as whey protein, corn flour, and carrageenan.

Meat proteins interact in gel matrix formation in both direct and indirect ways. It is important to take these factors into account in the formulation of meat products to reduce the expensive components of meat products and to replace them with an adequate proportion of cheap and under-utilized functional ingredients (CORTEZ-VEGA et al., 2013). Many plant-derived ingredients are used in meat products to perform functions such as water retention, binding of fat and forming of gel networks. However, consumers are increasingly demanding foods that contain fewer additives. Plant-based ingredients are perceived as additives and many are modified by chemical or other means. Thus, there is a large potential for the development of animal-derived ingredients, one example of that is surimi-like material from red meat or poultry (DESMOND; KENNY, 1998).

Surimi is considered an intermediate product as it is usually further processed into various other products. Due to its functional properties, especially its unique gelling capacity (CIERACH

et al., 2009), SLM can be a useful ingredient for the development of low-fat meat products. Moreover, BABJI et al. (1995) reported practical process surimi-like materials such as spent hen, old beef animal, mechanically deboned chicken meat and tilapia into surimi-like material into further products.

2.8.1. Restructured cured and cooked meat product

Restructured and comminuted sausages meat products are a diverse group of foods prepared with ground meats, added salt and spices (MURPHY et al., 2004). The ready-to-eat restructured cured and cooked meat products are included in this kind of meat products. The Brazilian legislation standard define the ready-to-eat restructured cured and cooked meat products as an industrialized meat product achieved from one or the diverse meat species of slaughtered animals, including edible kids, added from ingredients and submitted to a suitable heating process (BRAZIL, 2000). Furthermore, these products are commonly eaten as freshly cooked meat products to a breakfast or in combined forms in other meals (FAO, 2018).

Normative Instruction n^{o}. 20 (BRAZIL, 2000), about the technical regulate of identity and quality of ham sausage, which allow a maximum limit the addition of 30% mechanically deboned meat; 10% of edible kids; 2.5% of non-meat proteins as aggregated ingredient. It has also fixed herewith the physicochemical characteristics for the final processed ham sausage, as follows: 10% of total carbohydrates (maximum, including starch); 70% moisture (maximum); 12% protein (minimum); 5% starch (maximum); and, 0.45% of calcium content (maximum, in dry base composition) (BRAZIL, 2000).

Despite the adverse fat composition of the MDM (an ingredient), its color is also a dull brownish red if pigment oxidation has occurred, which may affect the color of mechanical deboned meat-containing meat products (SERDAROGLU et al., 2005).

Following the sense of the use of protein meat source, previous studies concerning meat products are available. For example, Hernandez, Baker and Hotchkiss (1986) tested the incorporation of range 5-20% washed mechanically deboned turkey meat from necks and ground turkey breast in cooked patties and observed that it has affected overall sensory quality. Then, they found that the use of 5% added washed mince became darker and did not be suitable to use its formulation in the sensory panel sections. In their studies, Wimmer, Sebranek and McKeith

(1993) washed mechanically separated pork using water or 1.5% salt solution (pH 5.5 and 6.5) and obtained surimi-like products for a further application for processing of frankfurters. They observed a little improvement over that unwashed mince for texture and water holding capacity and reduced lipid oxidation during storage. Therefore, they reported that the use of washed mince up to 50% in frankfurters resulted in samples with a soft texture. This finding comprises a controversy result of the gel characteristics.

A reduced effect on cooking loss with the application of 15% beef heart surimi in frankfurters when compared with the control was observed by Desmond and Kenny (1998). Other studies concerning the use of surimi and surimi-like materials in meat products were made by other authors, such as the imitation of crab sticks with chicken surimi-like (JIN et al., 2009), pork patties containing pork surimi-like (CHOI et al., 2012), burgers made with duck surimi (RAMADHAN, HUDA, & AHMAD, 2012), frankfurters made by washed mechanically deboned chicken meat (CORTEZ-VEGA et al., 2013), and *Kamaboko* made from MDCM (CORTEZ VEGA, PIZATO, & PRENTICE, 2014). Overall, all researchers reported that the final meat products were achieved good physicochemical and sensory characteristics.

2.8.2. Additives and ingredients

Ingredients comprise the nutritive components in foods, whereas additives are some substances directly added to a food in small portions during food processing for a specific purpose in that food. The additives remain in the final product independently of any goal of processing technology. Most direct additives are identified on the ingredient label of foods (BRAZIL, 1988). There are an extend list of allowed ingredients and additives added to hams and sausages, such as: water, salt (sodium chloride/sodium potassium), cassava starch, carrageenan, sugar, sodium polyphosphates, isolate soy protein, monosodium glutamate, preservatives (ascorbate/erythorbate) or curing salts (nitrite/nitrates), and others including colorants (BRAZIL, 1988). The purpose of directly added substances to foods is described as follow:

Water is routinely used as a food ingredient. Water serves as a carrier for salt and other ingredients providing a uniform distribution of these substances throughout the meat product. Ice or cold water is often used during the chopping process to cool a meat emulsion, thus ensuring an improvement of meat product stability (MASSINGUE, 2012). Water has also been added to

enhance the tenderness, juiciness and overall palatability of the product. In the new, low-fat processed meat product, water is used to replace fat, which also reduces caloric density (KEETON, 1994). For example, Murphy et al. (2004) observed that the levels of 25% surimi in combination with 6.3% fat and 28.5% water or 22% fat and 12.6% water were suitable to manufacturing of pork sausage product without adversely affecting its flavor, acceptability and consumer preference or its visual color and visual acceptability.

Salt is the main ingredient used in all curing mixtures and it is used for the purpose of developing flavor and for solubilizing proteins that are important for emulsion stability of comminuted and restructured meat products. Salt also helps in controlling microbial action in cured meats by lowering the water activity. Sodium chloride is the salt most commonly used in brine solutions, and its usage level varies with the type of product, being 1–2% in sausages, and 2–3% in hams (DIKEMAN; DEVINE, 2014).

Nitrite and nitrate are substances used in curing formulations for meats in order to stabilize the characteristic color of meat products, to inhibit the development of certain pathogens and to contribute for the development of the flavor associated with cooked cured meats (GANHÃO, 2011). It also provides oxidative stability to meat by preventing lipid oxidation and helps in controlling the development of warmed-over flavor in cooked, stored meats. Nitrite also serves as a vital bacteriostatic agent for control of the outgrowth of *Clostridium botulinum*, particularly under conditions of product mishandling. However, the addition of sodium nitrite to meat and meat products is highly regulated owing to the possible risk of formation of N-nitrosamine (DIKEMAN; DEVINE, 2014). In Brazil, the maximum allowable limit for the use of sodium nitrite, potassium nitrite, or their combinations in preserved meat and meat products (e.g. cooked ham sausages) is 150 ppm (BRAZIL, 2000).

The polyphosphates herewith soy isolate proteins are widely used in meat processing foods because they have the ability to improve the water holding mechanism (MASSINGUE, 2012; LEWIS; GROVES; HOLGATE, 1986).

2.9. Sensory analysis

Sensory analysis is a scientific discipline used to analyses reactions to stimuli perceived through the senses concerning appearance, texture, flavor, aroma, etc., which is a key for the food

industry where it serves as a tool in new foods development, quality control, process change investigation, shelf life evaluation, and other various numbers of applications (IFT, 1981).

Although the technology developments in instrumental analyses, such as texturometers, colorimeters, rheometers, etc. used for the empirical evaluation, still remain some uncertain answers which only the sensory tests could be the key of the real sensations about food characteristics in terms of appearance, texture, flavor and overall preference. Then, quality of food can is judged for their various sensory characteristics in different ways, using discriminative and descriptive tests (MINIM, 2006). Independently of which method could be selected for the sensory analysis, is suitable to assert that there are many benefits in conducting the sensory evaluation because it provides a clear understanding of product characteristics. Thus, it increases the company confidence relative to product quality and it identifies the sensory attributes driving consumer's preference (TALAVERA; CHAMBERS, 2017).

Recently, many researchers have conducted their sensory studies based on consumer preference tests, such as acceptance test and preference mappings. The preference mapping refers to a group of multivariate statistics techniques designed to develop a deeper understanding of consumer preferences for goods (NUNES et al., 2012). The reference mapping analysis takes an advantage than those of acceptance test, once the preference map represents the individual response of each consumer and their differences are easily shown graphically (MINIM, 2006), which are generally divided as internal and external preference mapping.

The internal preference mapping gives a representation of products and consumers which is obtained by singular value decomposition (e.g. Principal Component Analysis - PCA and Parallel Factor Analysis - PARAFAC) of a data matrix. The principal components evaluated, which are usually referred to as preference dimensions, are a graphical representation of products (scores) and consumers (loadings). According to Nunes et al. (2011), PARAFAC has advantages because provides a more evidence-based and general interpretation of the data, since the three-way internal preference map that is obtained by using them and the possibility of evaluating consumer acceptance data are simultaneously considered among various attributes.

On the other hand, external preference mapping (e.g. Check-All-That-Applies – CATA) derives a multidimensional representation of products based on their sensory profile or a set of other external data, such as instrumental measures of color, texture or flavor, called descriptive attributes (NUNES et al., 2012). The check-all-that-apply (CATA) is a sensory assessment tool

that is easier to understand and faster than the methods that use trained evaluators (ARES et al., 2010). This methodology was introduced by Adams et al. (2007). Since its introduction, this methodology for sensorial characterization has gained much prominence and several applications in the development of new products. These questions allow the respondents to select attributes relevant to them rather than analyzing all of the attributes of a scale (JORGE et al., 2015). Despite the limitations of the CATA questions that they do not allow a direct measurement of the intensity of perceived attributes, which could potentially hamper discrimination between products that have similar sensory characteristics but differ slightly in the intensity of those characteristics (MEYER; JAEGER; ARES, 2016), Ares and Jaeger (2015) and Jaeger et al. (2013) found that the CATA methodology does not seem to be impaired from the hedonic scores. This finding was also revealed by Bruzzone et al. (2015), showing that both results with the CATA intensity scales provided similar information to the descriptive analysis with trained tasters. Then, CATA has advantages because is less expensive than methods that involve a trained sensory panel (JORGE et al., 2015).

However, there is still a little number of published researchers that could be found using CATA questions involving meat products (MASSINGUE et al., 2018; OLIVEIRA et al., 2018; JORGE et al., 2015). These studies were done with 53, 50, and 86 judges, respectively, have reported that the CATA questions gave a good prospect to sensory evaluating of the final products. Though were are not found studies concerning the number of judges to compose the sensory panel for CATA questions, had been reported to be suitable panels composed by 40 to 100 judges (ARES et al., 2010; DOOLEY et al., 2010; PLAEHN, 2012).

3. FINAL CONSIDERATIONS

The purpose of this study was to evaluate the effect of repeated washes of the mechanically deboned turkey meat (MDTM) using different washing solutions to determine the best conditions to obtain the surimi-like material suitable to be used as substitute of the MDTM in emulsified and/or restructured cured and cooked meat products. Washing treatments is suitable to reduce fat and increase content, without significant changes in protein content. The use of surimi-like materials into the meat processed products provide non variations on its sensorial, physical and chemical characteristics, and become feasible to ensure the microbiological quality and extended shelf-life of the final product.

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PART TWO - ARTICLES

ARTICLE 1

Article drafted in accordance with the Food and Bioprocess Technology journal standard "Preliminary version"

Effect of washing cycles and solutions on quality characteristics of surimi-like material from mechanically deboned turkey meat

Abstract

To develop a surimi-like material from mechanically deboned turkey meat (MDTM), the effects of the washing solutions and washing cycles were evaluated on its composition and technological properties. Water, sodium chloride, sodium bicarbonate and potassium phosphate buffer were tested in one, two or three washing cycles. A microstructural analysis was evaluated using the scanning electron microscope tool for the surimi-like material. Overall, two washing cycles was effective ($P<0.05$) to increased water content and removing fat and heme pigments, obtaining surimi-like materials with good technological properties. Washing with sodium bicarbonate solution implied ($P<0.05$) in higher removal of sarcoplasmatic proteins and heme pigments, and resulted in washed MDTM with higher yield (37%), water holding capacity (0.39), pH (7.85), lightness (L^* = 66.86), hue tone (h = 60.11) and whiteness (60.47) values and lower chroma (C^* = 21.45) than other solutions. Phosphate buffer was also effective in removing sarcoplasmic protein and heme pigments, providing good lightness (L^* = 64.80) and whiteness (58.28). Removal of heme pigments increased ($P<0.05$) lightness and whiteness values among washed samples, except for that washed with water. Washing with water achieved the highest chroma (C^* = 30.87) and the lowest hue (h = 39.36), and it did not change among washing cycles. Therefore, washing MDTM with two cycles using a solution of sodium bicarbonate provide a desirable surimi-like material with highest technological quality.

Keywords: Mechanically deboned meat; Surimi-like material; Color characteristics; Microstructure.

Introduction

Turkey meat is the most produced poultry meat after broiler, and its production has increased. Brazil is ranked the second producer of turkey meat since 2004, and the largest worldwide exporter of poultry meat (FAO 2015). According with Brazilian Association of Animal Protein (ABPA 2017), in 2016 Brazil produced approximately 368 thousand tons of turkey meat, 62% of which was destined for the domestic market and 38% for exports.

In poultry cutting and boning operations, many by-products are left from less noble parts (neck, wing tips, frame and back bones, and skin), whose commercial value is lower. These underutilized parts are reused by the mechanical deboning process, generating a low-cost raw material commonly added as an ingredient in restructured cooked meat products and emulsified sausages. However, due to its composition (higher fat content, bone marrow and heme pigments) and characteristics (oxidation susceptibility, intense flavor, reddish color and perishability), the mechanically deboned meat has greater problems concerning of its appearance, texture and shelf-life that limit its addition in meat products (Moerck and Ball 1974, Froning 1981, Pereira et al. 2011; Cortez-Vega et al. 2013).

To overcome the problems associated with the mechanically deboned meat use in meat products, especially color and flavor concerns, the surimi processing has been suggested (Ramadhan et al. 2014; Cortez-Vega et al. 2014). Surimi is an original Japanese term referring to a white, tasteless and odorless myofibril preparation, obtained from mechanically deboned fish meat, washed with water several times and mixed with cryoprotectants (Stangierski, Zabielski, and Grzes 2013). When the protein concentrate is obtained by washing process on meats other than fish, the product is known as surimi-like material (Tina et al. 2010). The washing processing of meats with low marketing value has been considered in order to promote added-value of the raw material (Ismail et al. 2011; Cortez-Vega et al. 2012). Therefore, surimi-like products were made by utilization of different types of meat, such as seal (Shahidi and Synowieck 1993), beef (Park et al. 1996), pork (Park et al. 1996; Jin et al. 2009), lambs (McCormick et al. 1993), sheep (Antonomanolaki et al. 1999), laying hens (Nowsad et al. 2000), duck (Ismail et al. 2010; Ng and Huda 2011; Ramadhan et al. 2014) and chicken meat (Babji et al. 1995, Min and Lee 2004; Jin et al. 2009; Cortez-Vega et al. 2014).

Overall, surimi-like materials have not related to intense sensory taste or odors, but they are products with very good technological properties, primarily high water holding capacity and good thermal gelation (Antonomanolaki et al. 1999). However, the final quality of surimi-like materials obtained from washed meat is not always identical, depending on the raw material and recovery parameters, like the number of washings, the type of washing solution and the meat/water ratio (Stangierski 2013). Beyond water, sodium chloride (NaCl), sodium bicarbonate ($NaHCO_3$), and sodium phosphate buffer has been suggested as useful washing solutions for surimi-like material processing (Ramadhan et al. 2014).

Despite the production of turkey meat worldwide and the benefits of surimi process to enable the production of better quality meat products, the development of surimi-like material from mechanically deboned turkey meat (MDTM) has not been studied. Thus, the objective of this study was to develop a surimi-like material from MDTM by examining the effects of the washing solutions and number of washings cycles on the composition, technological and functional properties.

Material and Methods

Materials

Surimi-Like materials were prepared using mechanically deboned turkey meat (MDTM) donated by BRF® Brazil (Jundiai, SP, Brazil). Frozen MDTM blocks were transported to the Laboratory of the Meat Science and Technology (LabCarnes) on the Food Science Department of Federal University of Lavras (UFLA) and stored at -20 ^{o}C until surimi-like processing within the labeled validity date.

Turkey surimi-like material production

To produce the surimi-like material, frozen MDTM (-20 °C) blocks were cut into smaller sizes portions using a meat bone saw (CAF machine, Teresópolis, SP) and thawed overnight at 2 ^{o}C. The washing solutions evaluated were water, sodium chlorite solution (NaCl 0.086 M), sodium bicarbonate solution ($NaHCO_3$ 0.060 M) and potassium phosphate buffer (0.040 M; with

adjusted pH 6.8). The ratio of initial meat to the washing solution used was 1:4 (w/v) for all repeated washing procedures. A portion of meat was mixed with four portions of cold (<5 ^{o}C) washing solution (water, Sodium chloride, Sodium bicarbonate or Potassium phosphate buffer). Each washing cycle was performed under constant stirring at ~220 RPM using a propeller shaft agitator (Mechanical Agitator Ika, model RW 20, SP Labor, Brazil) for 10 minutes. After each stirring time, the mixture was allowed to stand for 5 minutes and the upper layer of fat was removed using a stainless-steel skimmer. The remained mixture was filtered and manually pressed into organza (cheese cloth filter) at the end of each cycle to remove excess water in meat concentrate, as suggested by Desmond and Kenny (1998). For each solution, the washing process was conducted once, twice and three times so that the effect of the number of washings on functional properties could be compared.

Washing solutions evaluation

After each washing cycle, the pH of the waste washing solution was measured using a digital pH meter (Digimed model DM20, SP, Brazil) and aliquots of 1 mL was removed, in triplicate, to determine the soluble proteins content (mg/mL) by the Biuret method (Ramos and Gomide 2017). The pH of the washing solutions before the washing process was also measured.

Yield and pH value

The surimi-like yield was calculated from differences between the weight of unwashed meat (MDTM) and ending mass of washed meat, expressed as a percentage of MDTM. The pH of unwashed and washed meat was also measured using a digital pH meter (Digimed model DM20, SP, Brazil) with an insertion electrode.

Chemical composition

The chemical composition of unwashed and washed meats was determined according to the official methods of the AOAC (2005). For proximate composition (%), samples were analyzed for the total moisture (AOAC 950.46B), fat (AOAC 960.39), protein (AOAC 981.10,

using 6.25 as conversion factor) and ash (AOAC 950.46) contents. Samples were also analyzed for calcium (% on a dry matter basis, DMB) and sodium (mg/100g), by the Atomic Absorption Spectrophotometry Method (AOAC 975.03) after dry ashing sampling preparation. The total protein recovery was determined by the mass protein content in washed meat in relation to the unwashed meat (MDTM): Protein recovery (%) = 100 × (%Protein washed meat × %yield / %Protein MDTM).

The total collagen content (mg/g) was determined by the hydroxyproline colorimetric method (AOAC 990.26), after 16 h hydrolysis (105 °C) of samples in sulfuric acid (AOAC 2005). The collagen content was calculated from hydroxyproline content using a 7.25 coefficient (Cross, Carpenter, and Smith 1973).

The heme pigments content was measured by the cyannet procedure proposed by Drabkin (1950) and described by Ramos and Gomide (2017). Approximately 2.5 g of unwashed and washed samples were homogenized with 12.0 mL of cold extraction solution (0.04 M Potassium phosphate buffer; pH 6.8) for 1 hour (4^{o}C) and filtered. The residue was re-extracted with the same procedure. The two filtrate solutions were mixed, and the volume completed to 30 mL with the extraction solution. After adding 3 mL of Drabkin reagent (60 mM $K_3Fe(CN)_6$ and 80 mM KCN), the extract was centrifuged (Hettich EBA21, Tuttlingen, Germany) at 3000×*g* for 15 min and the absorbance value of the supernatant was read at 540 nm by using a UV/Visible spectrophotometer (Thermo Scientific, São Paulo, Brazil). The total pigment content (mg/g sample) was calculated using the molecular weight (~17 kDa) of myoglobin and the millimolar extinction coefficient (11.3 L/mmol.cm) of cyanmethemoglobin.

Water holding capacity (WHC)

The WHC of unwashed and washed meats was carried out by the filter paper pressing method described by Aroeira et al. (2016). Samples of approximately 300 mg were placed onto a previously dried filter paper, and the assembly was pressed with a 5 kg-weight for 5 min. After pressing, the pressed meat area (PMA) and exudate liquid area (ELA) on the filter paper were obtained using the ImageJ®1.42q software (National Institute of Health, USA), and the WHC was expressed as PMA/ELA ratio.

Soluble proteins

The extractable soluble protein (mg/g) was determined using the method of Joo, Kauffman, Kim, and Park (1999), with minor modifications. Two grams of unwashed and washed meats were homogenized for 15 s at 27000 RPM with a Turrax homogenizer (Turratec TE-102, Piracicaba, São Paulo, Brazil) with 20 mL 0.03 M potassium phosphate buffer (pH 7.2) to extract soluble sarcoplasmic proteins, and with 20mL 0.55 M potassium iodide (KI) solubilized in 0.04 M potassium phosphate buffer (pH 6.8) to extract the total soluble proteins. The homogenates were settled off overnight at 4°C and centrifuged at 3000×*g* for 15 min. The fat layer floating on the supernatant was gently moved to one side screen with a stainless-steel spatula and aliquots of 1 mL were removed, in triplicate, for the protein content determination by the Biuret method as described by Ramos and Gomide (2017). The amount of soluble myofibrillar proteins was estimated by the difference in the total soluble proteins and the soluble sarcoplasmic proteins.

CIE color measurements

The unwashed and washed samples were placed in black plastics trays (15 x 15 x 2.7 cm) and tested by instrumental color, using a Minolta CM-700 (Konica Minolta Sensing Inc. Osaka, Japan) colorimeter with an 8-mm aperture size, illuminant A and a 10º angle of the observer. The device was calibrated to use the specular component included (SCI) and the specular component excluded (SCE) modes. Three measurements were collected from each sample and the spectral reflectance (between 400 and 730 nm; 10-nm interval) data were recorded.

The metmyoglobin (MMb) content was estimated by the Krzywicki (1979) mathematical method, using reflectance values (525 and 572 nm; determined by linear interpolation) obtained on the SCI mode. The CIE lightness (L^*), redness (a^*) and yellowness (b^*) components were obtained from the SCE mode readings. The color coordinates were expressed on the CIELCH system, with chroma (C^*) and hue angle (h) being calculated as (Ramos and Gomide 2017): $C^* = (a^{*2} + b^{*2})^{0.5}$ and $h = \tan^{-1}(b^*/a^*)$. Whiteness as the overall appearance index of the samples was calculated by the formula (Park, 2005): $Whiteness = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2}$.

Microstructural analysis

Samples were cut in cubes at the same height (5 mm), which were fixed in Karnovsky's Fixative (Paraformaldehyde 2.5%, Glutaraldehyde 2.0% in a buffer solution of sodium cacodylate 0.05 M, $CaCl_2$ 0.001 M, pH 7.2) and stored at 4 ^{o}C for 24 h. After fixation, the samples were dehydrated in a series of 25%, 50%, 75%, 90% and 100% acetone/water (v/v) for every 10 min into each solution; and three times for 10 min into 100% acetone, as described by Bozzola and Russel (1999). Finally, the samples were dehydrated in acetone removing by the critical point method with CO_2 in a Balzers CPD 030. They were coated with gold using *sputtering* Balzers SCD 050 equipment and observed in a Scanning Electron Microscope LEO EVO 40 (Carl Zeiss, Germany) at 15.02 kV and at a working distance of 7.5 mm. The images were scanned and digitized using software CorelDRAW X8, São Paulo, Brazil.

Statistical analysis

The experiment was conducted in a completely randomized design in a 4 (water, sodium chloride, sodium bicarbonate, and potassium phosphate buffer washing solutions) × 3 (one, two, and three washing cycles) factorial arrangement with four repetitions (batches), for a total of 48 experimental units. The effects of washing solution, number of cycles and their interaction were evaluated by ANOVA and, when necessary by Duncan test. The Dunnett's test was only used to compare washed meats (surimi-like materials) with the means of reference sample (MDTM).

All statistical analyzes were performed using the STATISTICA software (StatSoft Inc., Tulsa, USA), version 8.0, with significance level of 5%.

Results and Discussion

Washing solutions evaluation

Washing solutions were used with distinct pH media, as follows: sodium bicarbonate (8.2); sodium chloride (7.01); water (6.84); and potassium phosphate buffer (6.8). In preparation of surimi-like material products, pH and the nature of the buffering agents of the washing media

play important roles, not only about the stability of the product but also from a technological point of view (Cortez Vega et al., 2013). The effects of the successive washing cycles and washing solutions on soluble protein content and pH values in the wastewater are shown in Fig. 1. The effect of interaction between washing cycles and washing solutions was significant ($P<0.05$) for both protein content and pH.

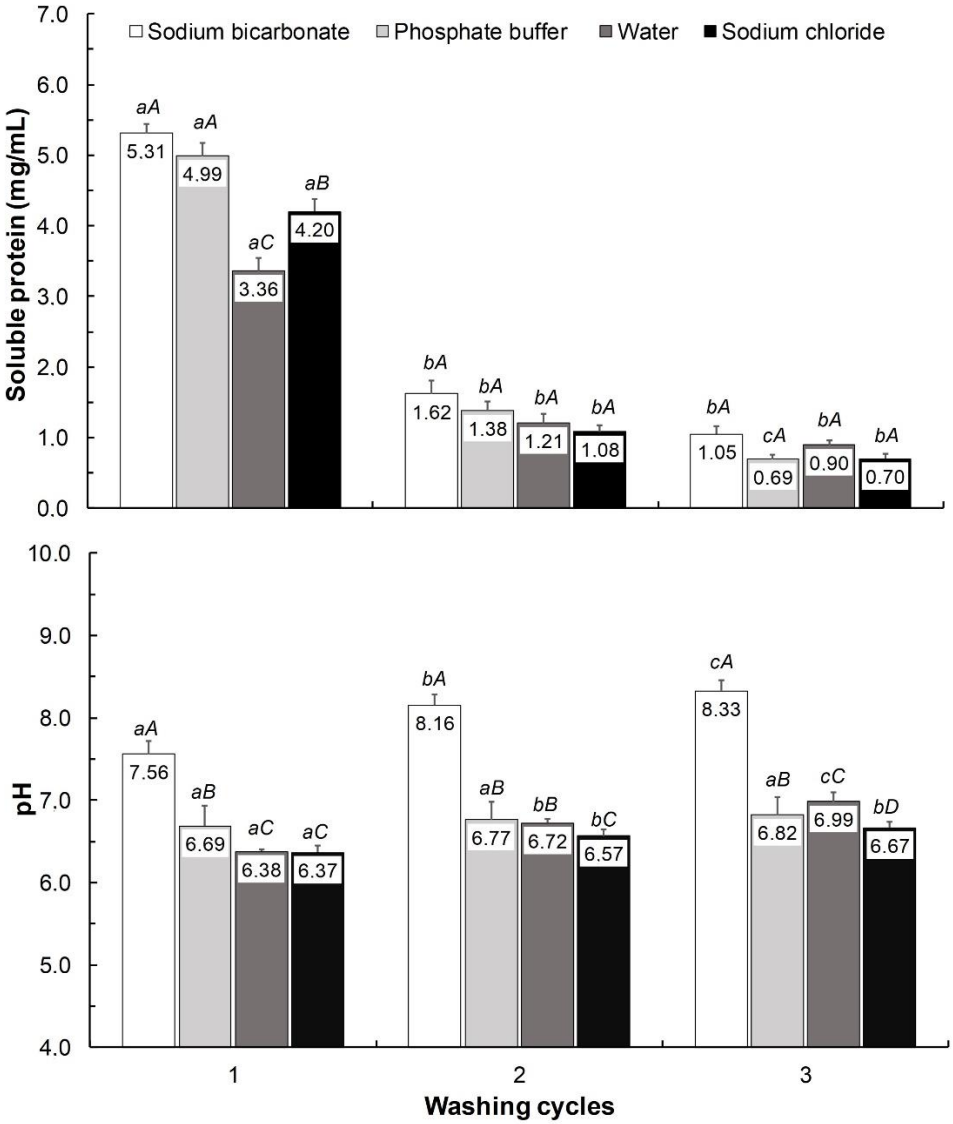

Fig. 1 Soluble proteins and pH values of wastewater from washed MDTM after washing cycles with different washing solutions (at 4°C). Bars with a common uppercase (*A-D*) for washing solutions within each cycle and lowercase (*a-c*) for the same washing solution in different cycles, did not differ ($P>0.05$).

Repeated washes increased pH of the waste washing solutions, except for that used phosphate buffer. The second cycle was crucial for pH rising mainly using sodium chloride. This effect has been widely reported as responsible for removing mainly water-soluble proteins (Lin, Park and Morrissey 1995; Park, 2005) during the surimi production. Fig. 1 shows evidently the highest water-soluble protein extraction after the first washing cycle (more than 60%). Washing with sodium bicarbonate and phosphate buffer extracted high protein than sodium chloride and water in the first washing, but after second washing cycle no difference was observed between washing solutions. These results were similar to those reported in the previous study (Yang and Froning 1992; Bonifer and Froning 1996). In the first washing, the highest protein extracting archived by sodium bicarbonate and phosphate buffer, could be attributed to higher pH media that favored greatly the removal of soluble proteins. The higher protein extraction of sodium chloride compared to water could be due to a higher salt-soluble protein removal, since the pH values were not different.

Physical and chemical characterization

Washing solutions and cycles affected ($P<0.05$) the process yield (Table 1). Reducing yield with an increased number of washes was expected, but in this experiment, after dropping by about 15% from the first cycle, the surimi-like yield was not different ($P>0.05$) between the second and third cycles. The three washings yielded a small amount of surimi-like material (31.7-37.2%) compared to values observed by Jin et al. (2009) on pork leg muscle after water-washed two and four times (45.1% and 54.1%, respectively), but it was higher than 23.2-26.2% reported by Ramadhan et al. (2014) after third washing of duck meat. Moreover, successive washings decreased ($P < 0.05$) the amount of recovery protein. The protein recovery in our study (34.5-46.5%) was lower than that of Yang and Froning (1992) who reported protein recovery of 51.2-58.8% after three successive washes of mechanically deboned chicken meat. However, it was estimated that approximately 50% of total proteins were lost during washing (Adu, Babbitt and Crawford 1983).

Several methods in surimi and surimi-like processing can result in different yields with the ranges of 23.2 to 70.5% compared with the started material (Babji et al. 1995; Jin et al. 2009; Hrynets et al. 2011; Cortez-Vega et al. 2013; Ramadhan et al. 2014). Variations noted between

laboratories are probably being due to several factors such as source material for mechanically deboned meat (MDM), grinding of MDM before washing, nature of washing media, washing time, adjustment of pH, number of washes, a ratio of MDM to extractant and force/pression applied during separation of meat material and extractant (Hudson 1994).

Table 1 Washing solutions (WS) and cycles (WC) effects on yield and protein recovery of surimi-like material prepared from mechanically deboned turkey meat (MDTM)

		Yield (%)	**Protein recovery (%)**
Washing Solution (WS)	Water	35.17±2.11^{ab}	44,78±3,98^{a}
	NaCl	30.98±3.49^{c}	39,03±6,96^{b}
	$NaHCO_3$	37.33±3.43^{a}	38,55±7,75^{b}
	PO_4-buffer	33.52±5.00^{b}	39,39±6,84^{b}
Number of washing cycles (WC)	1	37.21±2.81^{a}	46,56±4,50^{a}
	2	33.75±3.55^{b}	40,25±5,07^{b}
	3	31.79±4.46^{b}	34,50±4,73^{c}
Pr>F[1]	WS	***<0.001***	***0.001***
	WC	***<0.001***	***<0.001***
	WS x WC	*0.127*	*0.091*

NaCl = Sodium chloride 0.086 M; $NaHCO_3$ = Sodium bicarbonate 0.060 M; PO_4-buffer = Potassium phosphate buffer 0.040 M (pH 6.8)

[1]Significant probability (*P<0.05*) was shown in bold.

[a-c] Means in the same column, into each effect, followed by different letters differ (P < 0.05).

The washing solution had a different effect (*P<0.05*) on yield. The sodium chloride solution resulted lower surimi-like yield compared to the others washing solutions. Washing with phosphate buffer yielded similar amount of surimi-like material than that obtained by using water. These results agree with Ramadhan et al. (2014) that theorized that water-washing had higher yield by removing the fat and water-soluble proteins and retaining the salt-soluble proteins, while the sodium chloride solution removed higher amounts of salt-soluble protein. Like the water, the sodium bicarbonate solution had higher yield value, probably due to retaining more moisture compared to the other solutions (Table 2).

Table 2 Washing solutions (WS) and cycles (WC) effects on yield and chemical composition of surimi-like material prepared from mechanically deboned turkey meat (MDTM)

		Moisture (%)	**Fat (%)**	**Protein (%)**	**Ash (%)**	**Sodium (mg/100g)**	**Calcium (% DMB)**
Unwashed (reference)	MDTM	56.68±0.12	29.37±0.44	12.20±0.75	0.93±0.18	60.76±15.09	1.58±0.02
Washing Solution (WS)	Water	75.46±3.18^{a}*	7.14±2.64*	15.36±1.38^{a}*	0.81±0.09^{a}	7.95±4.19^{b}*	1.49±0.20
	NaCl	75.38±1.89^{a}*	6.42±1.37*	15.08±1.26^{a}*	1.06±0.11^{b}	65.93±30.10^{a}	1.40±0.18
	$NaHCO_3$	79.52±2.70^{b}*	5.87±1.45*	12.35±1.60^{b}	0.97±0.18^{b}	109.41±48.97^{a}*	1.50±0.23
	PO_4-buffer	76.42±1.42^{a}*	6.36±0.98*	14.15±1.17^{c}	1.29±0.10^{c}*	5.33±2.68^{b}*	1.39±0.16
Number of washing cycles (WC)	1	74.28±2.47^{a}*	7.85±1.88^{a}*	15.10±1.45^{a}*	1.03±0.18	40.41±18.92	1.39±0.19
	2	76.92±1.69^{b}*	6.36±0.91^{b}*	14.41±1.55^{a}	1.06±0.19	48.41±25.44	1.47±0.19
	3	78.88±2.36^{c}*	5.09±0.94^{c}*	13.19±1.84^{b}	1.01±0.26	58.87±38.50	1.48±0.21
Pr>F[1]	WS	***<0.001***	*0.054*	***<0.001***	***<0.001***	***<0.001***	*0.302*
	WC	***<0.001***	***<0.001***	***<0.001***	*0.458*	*0.797*	*0.376*
	WS x WC	*0.068*	*0.054*	*0.266*	*0.283*	*0.767*	*0.668*

NaCl = Sodium chloride 0.086 M; $NaHCO_3$ = Sodium bicarbonate 0.060 M; PO_4-buffer = Potassium phosphate buffer 0.040 M (pH 6.8); and DMB = dry matter basis.

[1]Significant probability (*P<0.05*) were shown in bold.

[a-c] Means in the same column, into each effect, followed by different letters differ (*P<0.05*).

* Means followed by an asterisk in the same column differ (*P<0.05*) from the reference sample (MDTM) by the Dunnett test.

The chemical composition of MDTM and washed meat are given in Table 2. No significant interaction effect ($P > 0.05$) was observed among washing solution and the number of washes for any of the evaluated parameters. However, the number of washings had a significant effect on the increase of moisture content and on the reduction of fat and protein content. The most obvious effects were that the washing increased moisture (from 56.68% of MDTM to around 74.28-78.88%) and reduced fat content (from 29.37% of MDTM to around 5.09-7.85%) of MDTM. This effect was expected in repeated washes with refrigerated solutions (4°C) since the stirring and the low density of the fat resulted in the fat float off and is removed. The amount of water content (moisture) in washed samples increases due to the concentration of protein and the reduction of its interaction with other components, such as fat, increasing its hydration.

Removal of fat is crucial in a surimi preparation since it will likely be oxidized and enhanced protein denaturation during frozen storage (Ng and Huda 2011; Ramadhan et al. 2014). In addition, a surimi containing a high level of fat tends to undergo lipid oxidation which impairs the flavor due to developing of rancidity (Park 2005). Thus, removing fat enhance the quality of surimi and demonstrate a suppression of lipid oxidation (Wimmer et al. 1993). Due to the raw materials fat content and method used, it was not possible to obtain a surimi-like product with below 3% of fat content as reported by other studies (Antonomanolaki et al. 1999; Cortez-Vega et al. 2013).

An effective washing process might remove both fat and sarcoplasmic proteins, but successive washes have implied on a reduced crude protein of the final surimi (Yang and Froning 1992; Ismail et al. 2010). Whereas, in our study was observed an increasing ($P<0.05$) protein content after one washing treatment than the reference (MDTM) sample. Thereby, after two or three washings, the protein content of washed samples was similar ($P>0.05$) to the unwashed MDTM. The similar result was reported by Antonomanolaki et al., (1999) who did not find differences in protein content of washed sheep meat during successive washes with water compared to that of unwashed mince. The previous study from Nowsad et al. (2000) also reported an increase of protein content after two washing cycles of spent hen meat.

The ash content (mean of 1.04 ± 0.21%) was not affected ($P>0.05$) by washes and did not differ ($P>0.05$) from unwashed MDTM. This not in accordance with other studies (Antonomanolaki et al., 1999; Ismail et al., 2010) who reported a significant decrease in this component due to successive washes. The successive washing cycles did also not affect

($P>0.05$) the sodium (mean of 49.23 ± 27.95 mg/100g) and calcium (mean of 1.45 ± 0.20% dry matter basis - DMB) contents. In their study, Shahidi and Synowiecki (1993) observed an increasing calcium concentration due to the washing process of washed mechanically separated seal meat.

Moisture, protein, ash and the mineral sodium content were affected ($P<0.05$) by the washing solution (Table 2). Samples washed with sodium bicarbonate solution had a greater amount of moisture (79.52%) in the surimi-like material than those washed by other solutions (75.75%). Ramadhan et al. (2014) reported similarly higher moisture content (79.7%, after third washing) when mechanically deboned chicken meat was washed with sodium chloride than those with other solutions, even than sodium bicarbonate (76.2%). Variations on moisture content in surimi-like material from laying hens, beef, and mechanically separated meat of chicken and Tilapia meat were early described (Babji et al. 1995). Despite the notable differences, in this study, high water content when sodium bicarbonate was used could be ascribed to the high pH values of its solution, leading to a high ability for hydration. According with Dawson et al. (1988), an increase in pH value can cause a significant increase of spaces among peptide chains due to repulsion among groups of proteins of equal load, allowing water to migrate into the tissue.

For protein content, values were lower ($P<0.05$) in the surimi-like material washed with bicarbonate solution compared to the other solutions, although the amount of protein recovered by sodium bicarbonate (Table 1) was the same as the sodium chloride and phosphate buffer solutions. This result could be due to the higher pH of bicarbonate solution which can promote the solubilization and loss of higher proteins in the wastewater than in other solutions (Fig 1). In addition, the high proportion of moisture in surimi-like material from sodium bicarbonate implies in a dilution in a proportion of solid components present in washed meat, such as protein content.

Ash content was higher ($P<0.05$) for phosphate buffer washings than others washing solutions and unwashed MDTM. This increasing content of ash could be due to potassium phosphate which is the greatest source of inorganic potassium and phosphorus, and it is a better buffer that maintains unvaried the pH value inhibiting extraction of inorganic salts during washings. About sodium content, water and phosphate buffer solutions induced lower ($P<0.05$) sodium content (6.64 ± 3.43 mg/100g) than sodium chloride and sodium bicarbonate solutions (87.67 ± 39.53 mg/100g) in surimi-like materials and even than unwashed MDTM (60.76 ± 15.09

mg/100g). This result was expected due to the amount of sodium in the solution composition, which might act replacing the water leached sodium during the washing process.

The successive washes decreased ($P<0.05$) the sarcoplasmic proteins and heme pigments (Table 3) contents. Washing procedure removes soluble compounds such as sarcoplasmic proteins, inorganic salts, low-molecular mass substances, lipids and blood components (Dewitt and Morrissey, 2002), and the first wash has been considered crucial in removing mainly sarcoplasmic proteins (Lin et al. 1995). In a comparison of the unwashed MDTM, from the first to third washes was observed a significant removing of sarcoplasmic proteins from 35 to 55%, and from 40 to 66% of heme pigments. Similarly, collagen content decreased ($P<0.05$) among washing cycles. However, the washed MDTM had higher collagen content than unwashed MDTM, as also observed by Shahidi and Synowiecki (1993) during seal surimi production. The increasing of collagen in surimi-like material could be ascribed to the accumulation of the insoluble fraction in the surimi-like material. This finding has been reported by previous studies as a residual concentration of insoluble collagen (Yang and Froning 1992; McCormick et al. 1993). Contrariwise, the myofibrillar soluble proteins were not affected ($P>0.05$) by the number of washings, although its concentration was higher (77.00 mg/g) than unwashed MDTM (29,18 mg/g).

According to Park (2005), protein solubility appeared limited to a certain level when the water/meat ratio, washing cycle, and washing time were constant. The collagen content was not affected (P>0.05) by washing solutions, but soluble proteins concentration among washed products differed ($P<0.05$) due to the different washing solutions. A lower ($P<0.05$) sarcoplasmic proteins content was reached into surimi-like material obtained with sodium bicarbonate and phosphate buffer, with sodium bicarbonate solution removing greater ($P<0.05$) amounts of heme pigment, presumably because the pH value of the slurry makes the blood proteins more soluble.

Table 3 Washing solutions (WS) and cycles (WC) effects on physicochemical characteristics of surimi-like material prepared from mechanically deboned turkey meat (MDTM)

		pH	Myofibrilar soluble proteins (mg/g)	Sarcoplasmatic soluble proteins (mg/g)	Heme pigments (mg/g)	Collagen (mg/g)	WHC
Unwashed (reference)	MDTM	6.39±0.12	29,18±11,19	31,05±10,25	5.43±0.72	0.37±0.11	ND
Washing	Water	6.53±0.14	76,52±10,18^{ab}*	22,83±6,30^{a}*	3.92±0.95^{a}*	0.88±0.26*	0.24±0.05
Solution (WS)	NaCl	6.67±0.15	80,47±18,93^{a}*	20,21±9,68 ^{a}*	3.47±1.23^{a}*	1.14±0.37*	0.27±0.06
	$NaHCO_3$	7.85±0.38	68,33±6,45^{b}*	11,05±4,11^{b}*	0.49±0.33^{b}*	0.97±0.37*	0.39±0.09
	PO_4-buffer	6.84±1.98	82,70±9,78^{a}*	12,47±3,73^{b}*	2.47±0.75^{c}*	1.07±0.19*	0.31±0.03
Number of	1	6.81±0.40	81,06±11,99*	20,06±7,73^{a}*	3.28±1.81^{a}*	1.19±0.32^{a}*	0.32±0.53
washing cycles (WC)	2	7.03±0.57	77,01±12,20*	15,72±7,85^{ab}*	2.59±1.45^{b}*	0.99±0.31^{ab}*	0.30±0.07
	3	7.08±0.70	72,94±14,42*	14,14±7,67^{b}*	1.86±1.21^{c}*	0.85±0.22^{b}*	0.29±0.12
Pr>F[1]	WS	***<0.001***	***0.044***	***<0.001***	***<0.001***	*0.276*	***<0.001***
	WC	***<0.001***	*0.207*	***0.031***	***<0.001***	***0.031***	*0.642*
	WS x WC	***0.002***	*0.935*	*0.882*	*0.328*	*0.734*	***0.043***

ND = note determined; NaCl = Sodium chloride 0.086 M; $NaHCO_3$ = Sodium bicarbonate 0.060 M; PO_4-buffer = Potassium phosphate buffer 0.040 M (pH 6.8); and WHC = water holding capacity.

[1]Significant probability (P < 0.05) were shown in bold.

[a-c] Means in the same column, into each effect, followed by different letters differ ($P<0.05$).

* Means followed by an asterisk in the same column differ ($P<0.05$) from the reference sample (MDTM) by the Dunnett test.

Washing with sodium bicarbonate also implies in lower ($P<0.05$) amounts of myofibrillar soluble proteins than sodium chloride and phosphate buffer, but with similar ($P>0.05$) content to that water-washed samples. This result implies that the lowest content of myofibrillar soluble proteins in the surimi-like material the greatest soluble protein losses during the washing process. To remove the fat and the residual sarcoplasmic proteins, the loss of a small amount of myofibrillar proteins is inevitable. With the MDTM homogenization during extraction, some of the fat is emulsified by the proteins, especially the myofibrillar ones, that are removed together. The high sarcoplasmic proteins content in washed MDTM by sodium chloride observed in this study is in accordance with Park (2005), who reported a reduced loss of myofibrillar proteins when 0.25-1.0% sodium chloride solutions was used, but it was not effective in removing the sarcoplasmic proteins even with increased washing cycles.

There was a significant interaction ($P<0.05$) among the number of washing and washing treatment for both pH values and water holding capacity (WHC), being decomposed and represented in Fig. 2. Primarily, after the first cycle all surimi-like materials had the same WHC. Washing MDTM for three times with sodium bicarbonate solution reached the highest ($P<0.05$) pH and WHC. The pH effect might have provided the higher WHC for sodium bicarbonate washed samples (Yang and Froning 1992; Jin et al. 2007; Ng and Huda 2011; Ismail et al. 2014). Although the pH of sodium bicarbonate was higher in all cycles, the WHC was higher ($P<0.05$) only after the third washing cycle in agreement with the increased ($P<0.05$) pH of third cycle.

Color analysis

The color indices of MDTM and surimi-like materials are given in Table 4. No significant interaction effect ($P>0.05$) was observed among washing solution and number of washes for lightness (L^*), metmyoglobin (MMb) content, and whiteness. However, the number of washing cycles and washing solutions had significant effects ($P<0.05$) on L^* values and whiteness, while washing solutions affected ($P<0.05$) MMb content.

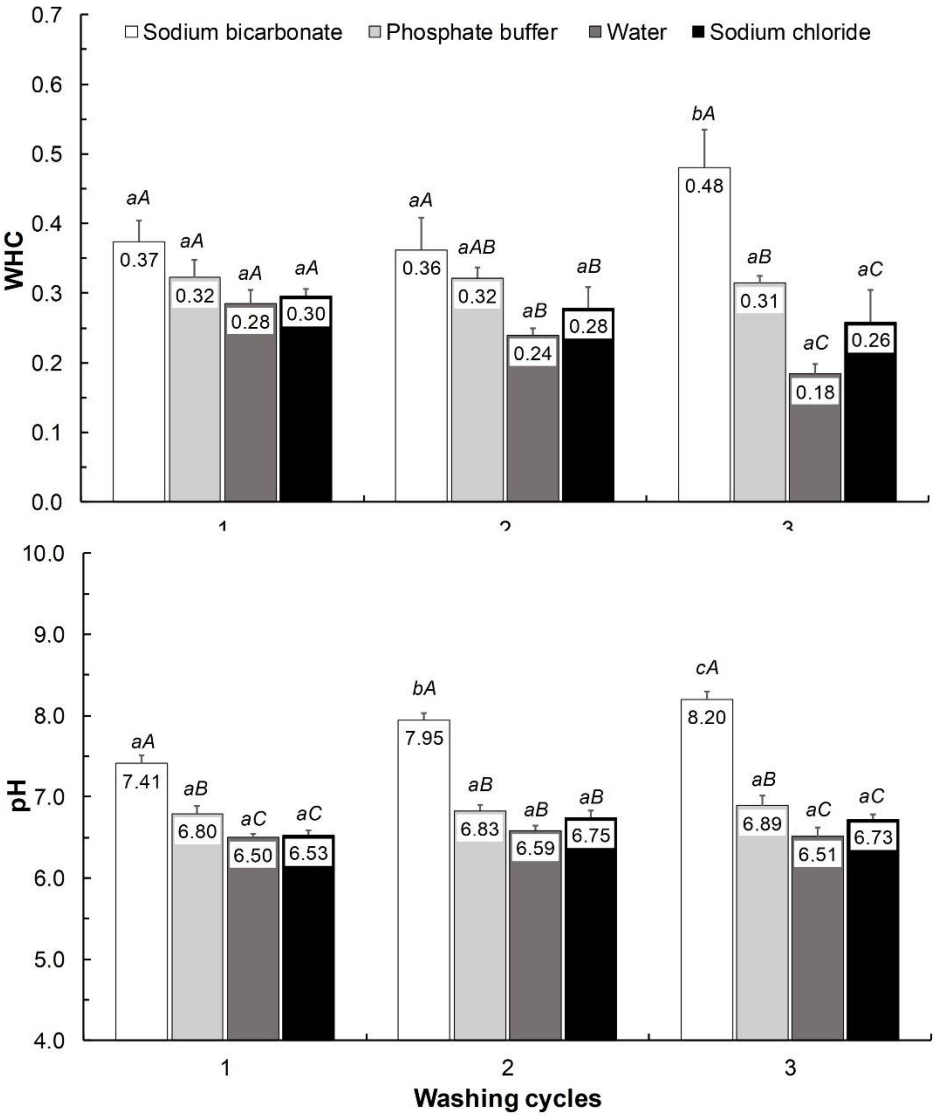

Fig. 2 pH and water holding capacity (WHC) values of washed MDTM after one, two or three washes with different washing solutions. Bars with a common uppercase (*A*-*C*) for washing solutions within each cycle and lowercase (*a*-*c*) for the same washing solution in different cycles, did not differ ($P>0.05$).

Table 4 Washing solutions (WS) and cycles (WC) effects on color indexes, metmyoglobin content (MMb) and whiteness of surimi-like material prepared from mechanically deboned turkey meat (MDTM)

		L*	***C****	***h* (graus)**	**MMb (%)**	**Whiteness**
Unwashed (reference)	MDTM	68.94±1.15	29.58±3.09	45.43±1.30	34.68±4.64	57.04±1.37
Washing	Water	56.49±1.51^{a}*	30.87±2.51	39.36±3.21	29.71±1.52^{a}*	46.60±1.61^{a}*
Solution (WS)	NaCl	62.11±3.66^{b}*	25.40±2.35	48.06±3.94	35.40±3.46^{b}	54.35±3.94^{b}
	$NaHCO_3$	66.86±1.77^{c}*	21.45±2.94	60.11±5.72	39.16±2.55^{c}*	60.47±2.73^{c}
	PO_4-buffer	64.80±1.98^{d}*	22.35±1.93	53.64±4.46	37.02±2.57^{b}	58.28±2.25^{d}
Number of	1	61.26±4.15^{a}*	27.19±3.15	46.67±5.22	34.58±4.36	52.64±4.93^{a}*
washing cycles (WC)	2	62.85±5.02^{ab}	25.22±4.79	51.17±8.87	35.02±4.36	55.06±6.66^{b}
	3	63.58±4.43^{b}	22.64±4.43	53.04±10.69	36.36±4.41	57.08±5.71^{c}
Pr>F[1]	WS	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***
	WC	***0.026***	***<0.001***	***<0.001***	*0.138*	***<0.001***
	WS x WC	*0.606*	***0.042***	***<0.001***	*0.494*	*0.168*

NaCl = Sodium chloride 0.086 M; $NaHCO_3$ = Sodium bicarbonate 0.060 M; and PO_4-buffer = Potassium phosphate buffer 0.040 M (pH 6.8).

[1]Significant probability (*P<0.05*) was shown in bold.

[a-d] Means in the same column, into each effect, followed by different letters differ (*P<0.05*).

* Means followed by an asterisk in the same column differ (*P<0.05*) from the reference sample (MDTM) by the Dunnett test.

All washed samples were darker (lower *L**) after first washing cycle, but they became lighter and whiter (high whiteness) with two and third washing cycles. Ramadhan, Huda and Ahmad (2014) who reported that *L** and whiteness of ground duck meat were improved with repeated washes. However, in this experiment, all washed samples were ($P<0.05$) darker and, except for water-washed, had similar ($P>0.05$) whiteness values than unwashed MDTM. Ismail et al. (2010) observed a decrease of these values in surimi-like materials obtained from duck meat after three and four washing cycles with water, which they considered to have been due to the oxidation of myoglobin to metmyoglobin (MMb) or to the resulting from the reduction of MMb to a deoxymyoglobin (Mb). A change in the MMb content with subsequent washing cycles was not observed ($P>0.05$) in this experiment. Moreover, water-washed samples had the lowest ($P<0.05$) MMb content and whiteness compared to all other samples. Sodium chloride and phosphate buffer washed samples had similar ($P>0.05$) MMb content, while sodium bicarbonate washed samples had the highest ($P<0.05$) MMb content, presenting lighter and whiter than all treatments. However, the MMb interference in the bicarbonate-washed surimi color is probably unrelenting due to the low amount of heme pigments (Table 3) in this material.

The lower *L** values and whiteness observed for washed samples compared to unwashed MDTM could not be explained by the MMb content. However, these could be attributed to a difference in pH values and hydration of the protein matrix, which affect the surface light scattering. According to Ramos and Gomide (2017), the lightness of meat color depends to the penetration and absorption of incident light by the pigments, but also to the difference between the refractive indexes of protein matrix, which are fundamentally associated with the structural condition of the proteins. Therefore, in the unwashed MDTM samples, there are differences in refractive indexes, due to protein denaturation (lower total soluble protein; Table 3) during its obtaining, and light is dispersed on the surface, reducing its depth of penetration and absorption by heme pigments; these makes the MDTM pale (higher *L** values). With washing, the proteins were solubilized, and in some cases concentrated, forming a hydrated protein matrix with a large volume and, therefore, with low differences in the refraction index. In this case, the light scattering ability is low and the incident light is deep, implying in less dispersion and greater absorption of light by the heme pigments, making the meat darker. This also explained the higher chroma (*C**) values of washed samples compared to the unwashed MDTM, which suggests a more intense color.

Beyond *L** values, the surimi-like CIE color was evaluated by the polar coordinates chroma (*C**) and hue angle (*h*): higher *C** values suggests more vivid color; and samples with *h* values near 0º are red and near 90º are yellow (Ramos and Gomide 2017). An interaction between washing cycles and the different solutions were observed (*P<0.05*) for the *C** and *h* (Table 4), being represented in Fig.3.

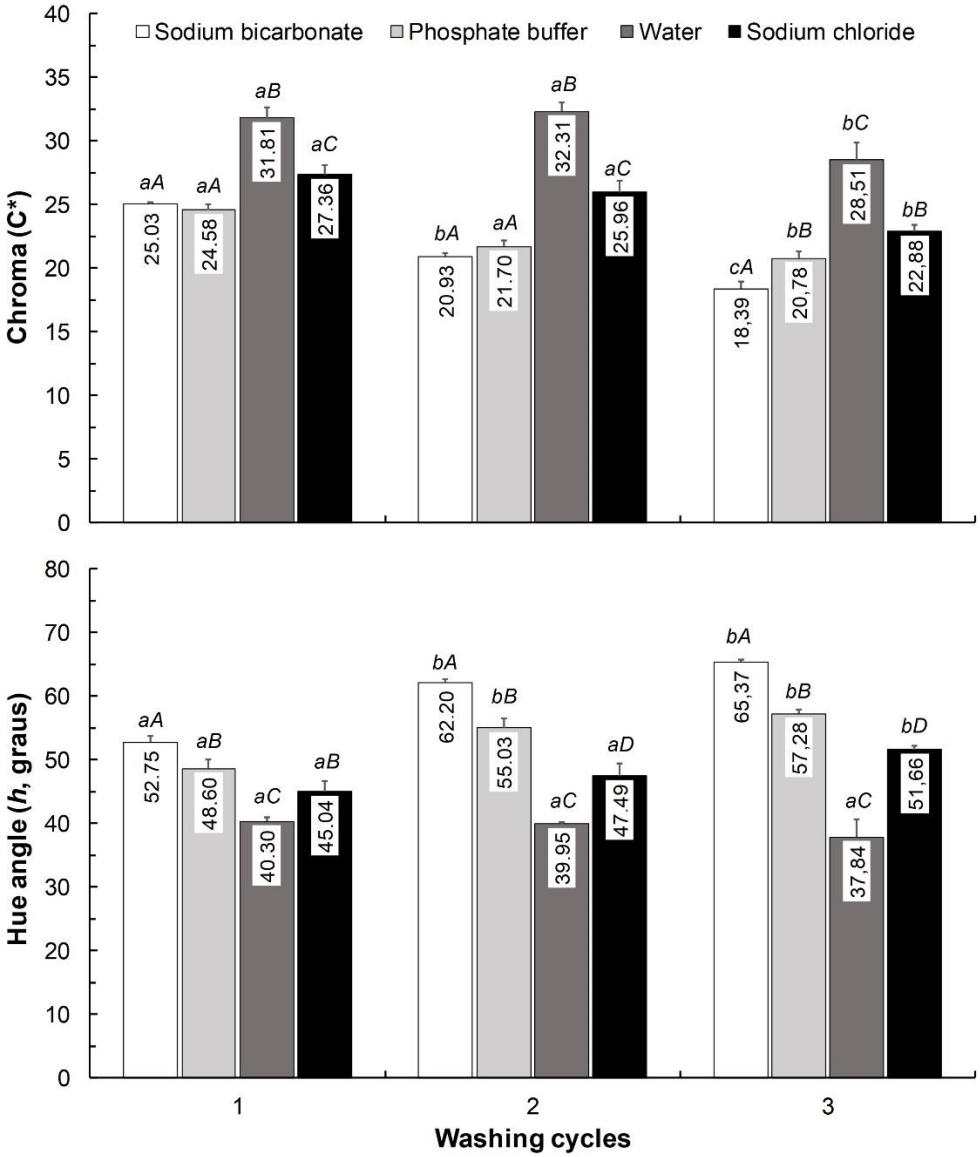

Fig. 3 CIE chroma (*C**) and hue angle (*h*) values of washed MDTM after one, two or three washes with different washing solutions. Bars with a common uppercase (*A-D*) for washing solutions within each cycle and lowercase (*a-c*) for the same washing solution in different cycles, did not differ (*P>0.05*).

Except for the *h* values of washed samples, the *C** and *h* values have significantly changed (*P<0.05*) due to the washing cycles up to higher *h* and lower *C** values. These changes are related to the heme pigment loss with repeated washing cycles. Water followed by sodium chloride washed samples had highest *C** values than all other solutions in all washing cycles, which means more intense color and should also be related to the highest heme pigment retaining in these samples (Table 3). Despite water washing did not change (*P>0.05*) the *h* values during the washing cycles, all water washed samples were redder (*P<0.05*) compared to those achieved by other washing solutions. Fig. 4 illustrate the washed MDTM color with different washing solutions and washing cycles.

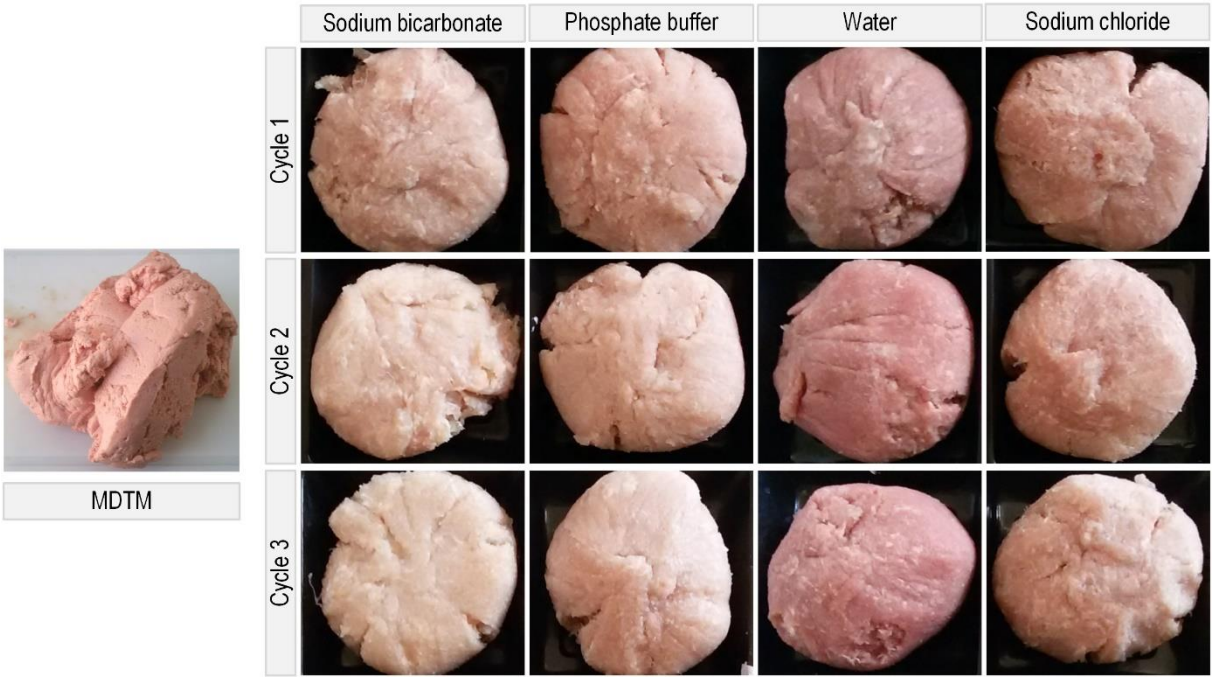

Fig. 4 Pictures of the surimi-like from mechanically deboned turkey meat (MDTM) washed with different solutions and by different washing cycles.

Microstructural analysis

Scanning electron microscopy (SEM) was used to examine the cutting sections of the surimi-like materials obtained with different washing solutions. The washed meat micrographs are presented in the Fig. 5.

The cutting section of washed meat with water and sodium chloride solution exhibited large cavities and cracked lines, which may be were formed due to the weak linkage between proteins. This might be related to the myofibrillar proteins lower density which can diminish

the protein matrix arrangement in raw meat and could be explained by its lower water holding capacity. In addition, darker and lighter areas were observed on the water washed meat structure, but little lower dark spaces were observed when sodium chloride was used. This also explains the lowest extractability of soluble proteins in wastewater solutions in their obtained surimi-like materials. This result suggests that the dehydration procedures have removed the remained water after fixation, hence cavities areas in the surimi-like materials.

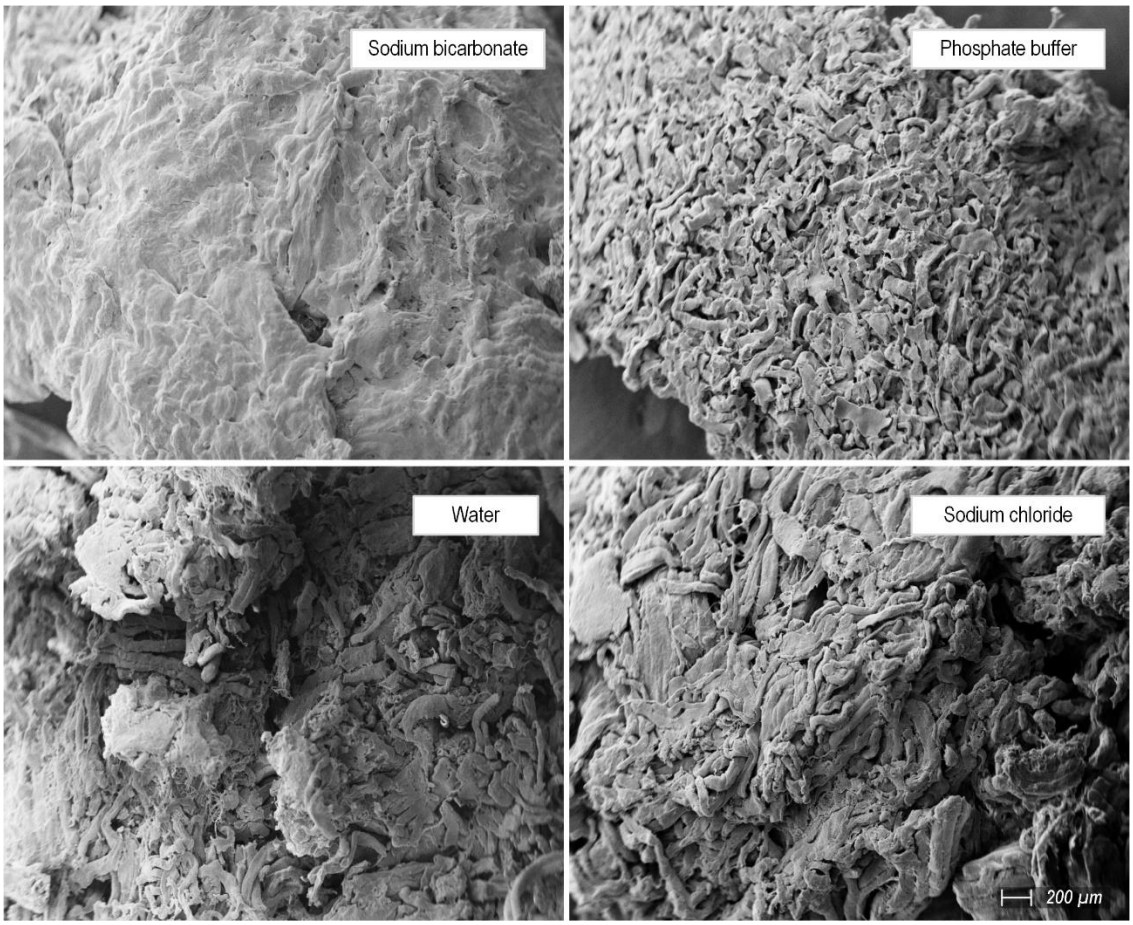

Fig. 5 Scanning electron micrographs (SEM; magnification 65x) of surimi-like material from mechanically deboned turkey meat (MDTM) washed with sodium bicarbonate 0.060 M, potassium phosphate buffer 0.040 M (pH=6.8), water and sodium chloride 0.086 M.

The cutting sections of the sodium bicarbonate washed MDTM showed a whole dense and brighter (high lightness) matrix structure. The washing procedure increased the water content of the mince and the surimi-like material obtained has swelled due to high pH and water holding capacity values that caused a distention of membrane structures and myofibrils network resulting to that smooth dimension structure. The small cavities observed could be

due to the removing of airbags during the critical point dehydration, whereas the water maintained of the proteins bound. Finally, the washed MDTM using phosphate buffer also exhibited a homogeneous tri-dimension structure. Protein aggregation was possible maybe due to the lower variation of pH values which maintain the stability of the protein structure. There is also visible that meat proteins were connected and formed a compact fibrous matrix. These characteristics could be explained by the good extraction of sarcoplasmic proteins and slightly improved water holding capacity of the buffer washed mince.

Conclusions

The chemical composition and physicochemical properties of the surimi-like materials obtained from mechanically deboned turkey meat (MDTM) were affected by the number of washings and washing solutions. Two washing cycles was effective to allowed removing amount of fat, maintaining the proteins, and obtaining surimi-like materials with good technological properties. Washing with sodium bicarbonate achieved the highest pH and water holding capacity, and exhibited the most efficient removing heme pigments, which improved lightness and whiteness color. Thus, among the solutions used in this study, it is concluded that the sodium bicarbonate seems to be the best washing solution, used at least for two washing cycles, to obtain a lightened surimi-like material with highest technology quality for further utilization in the manufacture of low-fat meat products.

Acknowledges

The author would like to thank the Brazilian funding agencies Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq; 430206/2016-0) and the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG; CVZ APQ-02015-15 and CVZ APQ-02904-17) for their financial support. The author also grateful to the Government of Mozambique and to the Brazilian agency Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the scholarship granting (Doctorate Degree) by the Programa de Estudantes-Convênio de Pós-Graduação (PEC-PG/CAPES).

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ARTICLE 2

Article drafted in accordance with the Asian-Australasian Journal of Animal Science standard "Preliminary version"

Textural properties of surimi-like gels obtained from mechanically deboned turkey meat by different washing solutions

Objective: This work proposed to evaluate the textural gel properties of turkey surimi-like (TSL) materials obtained from mechanically deboned turkey meat (MDTM) by different washing solutions and washing cycles.

Material and Methods: Twelve different TSL materials were obtained by washing (in one, two or three cycles) MDTM with four different solutions: water, sodium chloride (0.086 M), sodium bicarbonate (0.06 M), and potassium phosphate buffer (0.04 M; pH 6.8). Each TSL was homogenized without and with 2% sodium chloride (salt) before submitted to thermal gelation, and analyzed about cooking loss and texture profile. Color and microstructural analysis was also carried out to visual assessment.

Results and Discussion: TSL gels were markedly affected by ionic strength. Addition of salt reduced ($P<0.05$) cooking loss and increased ($P<0.05$) hardness and chewiness. Gels from sodium bicarbonate had the lowest ($P<0.05$) cooking loss and hardness, independently of the added salt, while its adhesiveness increased ($P<0.05$) after two washes in that samples containing 2% added salt. Scanning electron micrographs showed a fine-stranded gel structures formed at low ionic strength and coarsely aggregated gel structures at high ionic strength. Washing with sodium bicarbonate solution resulted in gels with high lightness and whiteness desirable color.

Conclusion: The results demonstrate that the salt addition improved the gelling properties of protein concentrates. Two washes of MDTM with sodium bicarbonate solution generates high-quality colorless gels of TSL with proper textural properties and is suggested as a potential alternative to be used in the manufacture of surimi-based foodstuffs.

Keywords: Protein concentrate; Thermal gelation; Texture profile analysis; Color.

INTRODUCTION

Mechanically deboned turkey meat (MDTM) is a common ingredient in meat products, but its dark color, textural properties and susceptible to lipid oxidation are undesirable in meat processing. To reduce these problems, washing can be used to obtain products characterized as "surimi-like", in reference to the washing process traditionally used in fish to produce "surimi" [1]. Almost all surimi and surimi-like materials are manufactured by repeatedly chilled water-washing to remove undesirable substances, such as sarcoplasmic proteins, lipids, and lower molar water-soluble materials, leaving a tasteless and odorless myofibrillar protein product with unique textural properties [2].

Approaches in mechanically deboned poultry surimi-like production revealed profound interests by washing using water [3, 4], and weak ionic strength, like phosphate buffer solution with pH 5.8 to 8.0 [4, 5, 6], sodium chloride [4, 7, 8] and sodium bicarbonate [3, 4, 9]. No longer, other studies found that all selected washing treatments were effective for the removal of heme pigments [10, 11, 12], obtaining high myofibrillar protein concentration. Like fish surimi, surimi-like from poultry meat has been rarely studied as food materials [4, 10, 12, 13] and this textural characteristics and stability depends on the inherent characteristics of its proteins, as well as on external factors; primarily temperature, pH, protein concentration and salt (NaCl) additions [14, 15].

Protein gelation is an important feature in food because it determines the sensorial properties of food, especially its texture, which determines whether a product is accepted by the consumer [16]. The effect of salt addition on cooked gel formation was described by some little previous studies [17, 18]. Highlights are given for commonly 1.2 to 2.0% added salt in the commercial surimi, although the use of 2% added salt in gel testing can be more practical [14], since represents the maximum amount of salt commonly used in cooked meat products. Although Park et al. [17] reported good gel-forming ability when they used 1.5 or 3.0% salt added in beef or pork surimi, Park [14] pointed that the use of 3% salt could overestimate the surimi gel quality. On the other hand, Sun and Holley [19] confirmed that a concentration of 2-3% of sodium chloride is required to solubilize the myofibrillar proteins to form a good gel. These authors also found, however, that are evidence that solubilization of the myofibrillar proteins is not an absolute necessity, and good gels can be made without salt.

Previous experiment [4] describes the development of surimi-like materials from MDTM with different washing solutions and washing cycles, obtaining protein concentrates with higher quality properties for further utilization in the manufacture of low-fat meat products. However, the effects of the treatments (washing cycles and washing solutions) and the salt addition on the gelation properties were not assessed. Therefore, the objective of this study was to investigate the effects of washing solutions and number of washings cycles on the textural properties of salted and unsalted gelled surimi-like material obtained from MDTM.

MATERIAL AND METHODS

Preparation of turkey surimi-like gels

The turkey surimi-like (TSL) materials used in the present work were the same as described in a previous report [4]. Briefly, one portion of frozen mechanically deboned turkey meat (MDTM; Frozen donated by BRF® Brazil; Jundiaí, São Paulo, Brazil) was thawed in 4 volumes of different chilled (< 5 °C) washing solutions (water; 0.086 M sodium chloride; 0.06 M sodium bicarbonate; and 0.04 M potassium phosphate buffer, pH 6.8) and homogenized (at 220 rpm) for 10 min using a propeller shaft agitator (Mechanical Agitator Ika, model RW 20, SP Labor, Brazil). After first stirring time (cycle), the upper layer of fat was removed using a stainless-steel skimmer and the slurry filtered and pressed in cheese cloth to remove excess water. The remaining residue was resuspended with 4 volumes of the original wash solution, homogenized (220 rpm/10min) and filtered and pressed again in cheese cloth (second cycle). These procedures were repeated for obtained the third cycle. For each washing solution, residues of the three cycles were used as TSL in this experiment.

The 12 different (3 washing cycles x 4 washing solutions) heat-set gel preparations were conducted with an original (without salt addition) and sol (with 2% salt addition) TSL material. Each TSL (with and without salt) was homogenized in a cutter mixer (Philips Walita, ProMix) for 30 s until the mixture resembled a meat batter. The temperature of the mixture was kept below of 5 °C during mixing. Samples were weight into 50 mL centrifuge tubes, centrifuged at 3,000*g* for 15 min to compact the batter and sustained at 4 °C for 1 h to equalize their temperature. The tubes were put in a water bath at 35 °C and, then, the bath temperature was set

to 75 °C and the sample core temperature was accompanied by a thermocouple (MT525 thermometer, Minipa industry Co., Ltd., São Paulo, Brazil) until reaches 71 °C (cooking time mean of 30 min). Heat-set gels were immediately chilled in an ice water bath for 15 min and the exudates were drained. Paper towels were used to remove any remaining moisture on the gel surface and the final weight was recorded to determine the cooking loss.

Texture profile analysis

The texture profile was performed as described by Ramos and Gomide [20], using a TA.XT2i universal texture analyzer (Stable Micro Systems Ltd., Surrey, England). Gels were cut into cylinders (1.5 cm diameter x 1.5 cm height) and compressed twice to 60% deformation of their original height with a flat cylindrical compression aluminum probe (36 mm diameter). A cross-head speed of 180 mm/min was applied and there was no time of rest between the two compression cycles. Force time curves were recorded during compression and texture attributes were calculated as follows: 1) hardness (N), peak force required for the first compression; 2) springiness (mm), distance sample recovers after the first compression; 3) adhesiveness (N×mm), the negative force area for the first bite representing the work necessary to pull the compressing plunger away from the sample; 4) cohesiveness, ratio of positive force area during the second compression to that in the first compression; and 5) chewiness (N×mm), the product of hardness, cohesiveness, and springiness.

CIE color and microstructural analysis

CIE color and microstructural analysis was carried out to visual assessment of the gel color and texture. These analyses were conducted in TSL samples obtained after the second washing cycle, since in previous report [4] it was suggested that two washing cycles was sufficient to obtaining surimi-like materials with good technological properties.

The Gels CIE color were evaluated using a Minolta CM-700 (Konica Minolta Sensing Inc. Osaka, Japan) colorimeter with an 8-mm aperture size, illuminant A, 10º angle of the observer and specular component excluded (SCE) mode. The CIE lightness (L^*), redness (a^*) and yellowness (b^*) components were obtained on the internal surface of three cylinders cores

(25-mm height) from each sample. CIE color coordinates were expressed on the CIELCH system with chroma (C^*) and hue angle (h, graus) calculated as: $C^* = (a^{*2} + b^{*2})^{0.5}$ and $h = \tan^{-1} (b^*/a^*)$. Higher C^* values suggest more vivid color, and h values near 0° are red and near 90° are yellow [20]. Whiteness as the overall appearance index of the samples was calculated by the formula [4]: $Whiteness = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{0.5}$.

The microstructural evaluation was conducted by scanning electron microscopy (SEM) analysis as described by Bozzola and Russel [21]. Cubes of 0.5 cm length were fixed in Karnovsky's Fixative (buffer solution of sodium cacodylate 0.05M, CaCl2 0.001M, pH 7.2 with 2.5% paraformaldehyde and 2.0% glutaraldehyde) at 4 °C for 24 h. After fixation, samples were dehydrated for 10 min into a series of 25%, 50%, 75% and 90% acetone (acetone/water, v/v) and three times for 10 min into 100% acetone. Samples dehydration has been performed by the critical point drying CPD 030 device (BAL-TEC AG, Balzer, Germany), coated with gold using sputtering SCD 050 device (BAL-TEC AG, Balzer, Germany) and observed in a Scanning Electron Microscope LEO EVO 40 (Carl Zeiss, Germany) at 15.02 kV and at a working distance of 7.5 mm.

Statistical analysis

The statistical analysis was conducted in a completely randomized design, with a factorial arrangement of 4 (washing solutions) x 3 (washing cycles) x 2 (salt levels) with 3 repetitions (batches). Main and interaction effects of functional properties were evaluated by ANOVA, and when necessary by Duncan test using software SAS 9.2 (SAS Institute Inc., Cary, NC, USA) package, with significance level of 5%.

RESULTS AND DISCUSSION

Cooking loss and texture profile analyzes

The effects of washing solutions, washing cycles and salt addition on the cooking loss and texture profile attributes of turkey surimi-like gels were shown in Table 1.

Table 1. Effects (means ± standard deviation) of washing solutions (WS), washing cycles (WC) and salt level (SL) on cooking loss and texture attributes of turkey surimi-like gels.

Effect	Source of variation	Cooking loss (%)	Hardness (N)	Cohesiveness	Adhesiveness (N×mm)	Springness (mm)	Chewiness (N×mm)
Washing solutions	Water	24.36±7.04	45.80±5.04	0.45±0.03	0.09±0.11	26.44±1.35	538.40±208.63
(WS)	NaCl	22.45±9.25	46.31±10.57	0.41±0.02	0.12±0.09	26.11±1.53	512.14±150.55
	$NaHCO_3$	10.68±6.24	25.74±11.44	0.39±0.05	0.32±0.22	25.59±1.73	296.04±185.12
	PO_4-buffer	20.48±8.36	46.28±12.43	0.41±0.02	0.07±0.04	25.73±1.41	433.49±161.43
Number of washing	1	18.38±8.48	44.67±16.16	0.40±0.03^{a}	0.11±0.07	26.03±1.81	484.22±221.26
cycles (WC)	2	19.48±8.92	42.01±13.68	0.42±0.05^{ab}	0.20±0.24	26.19±1.33	459.77±172.32
	3	20.61±10.63	36.43±14.81	0.43±0.03^{b}	0.14±0.12	25.67±1.38	391.06±194.47
Salt level, % (SL)	0	26.42±6.66	32.20±12.02	0.41±0.04	0.12±0.11	25.09±1.37^{a}	326.41±158.38
	2	12.56±5.69	49.86±12.58	0.42±0.03	0.18±0.20	26.84±1.11^{b}	563.63±160.35
Pr>F[1]	WS	***<0.001***	***<0.001***	***<0.001***	***<0.001***	*0.119*	***<0.001***
	WC	***0.022***	***<0.001***	***0.026***	***<0.001***	*0.270*	***<0.001***
	SL	***<0.001***	***<0.001***	***0.045***	***<0.001***	***<0.001***	***<0.001***
	WSxWC	*0.134*	***<0.001***	*0.909*	***<0.001***	*0.361*	***<0.001***
	WSxSL	***0.003***	*0.087*	***<0.001***	***<0.001***	*0.057*	***0.001***
	WCxSL	***0.005***	*0.914*	*0.867*	***<0.001***	*0.073*	*0.906*
	WSxWCxSL	*0.952*	***0.039***	*0.363*	***<0.001***	*0.273*	***<0.001***

NaCl = sodium chloride 0.086M; $NaHCO_3$ = sodium bicarbonate 0.06M; and PO_4-buffer = Phosphate buffer 0.04 M (pH 6.8).

[1]Significant probability (*P<0.05*) was shown in bold.

[a-b]Means with different superscript letter, within a column and for each effect, differ (*P>0.05*).

For cooking losses, interactions were observed (*P<0.05*) between salt addition and washing solutions as well as salt addition and washing cycles. Overall, the 2% added salt decreased (*P<0.05*) the cooking losses of heat-set gels, independently of the washing solution or the washing cycle applied. Low cooking loss might be mainly a function of protein-protein interaction resulting in an open matrix, thereby allowing a higher proportion of total water to be immobilized than in meat proteins with strong protein interactions [22]. Salt solubilizes the myofibrillar proteins, improving its functionality and, therefore, increasing protein-water and protein-protein binding with better gelation [18, 23], with implies in cooking losses reductions.

Heat-set gels without salt addition had lower (*P<0.05*) cooking losses when washed by one or two than by three cycles (Fig. 1), which could be due impair to the lower ionic strength, and lower ability of water binding, and for the lower protein content in surimi-like materials, as observed by Massingue [4] that the washing process reduced the protein content from 14.76% with 1 and 2 cycles to 13.19% with 3 cycles. However, despite a slight increase in cooking loss due to the repeated washes in gels without salt additions, there was no differences (*P>0.05*) in the cooking losses values of 2% salty surimi-like gels.

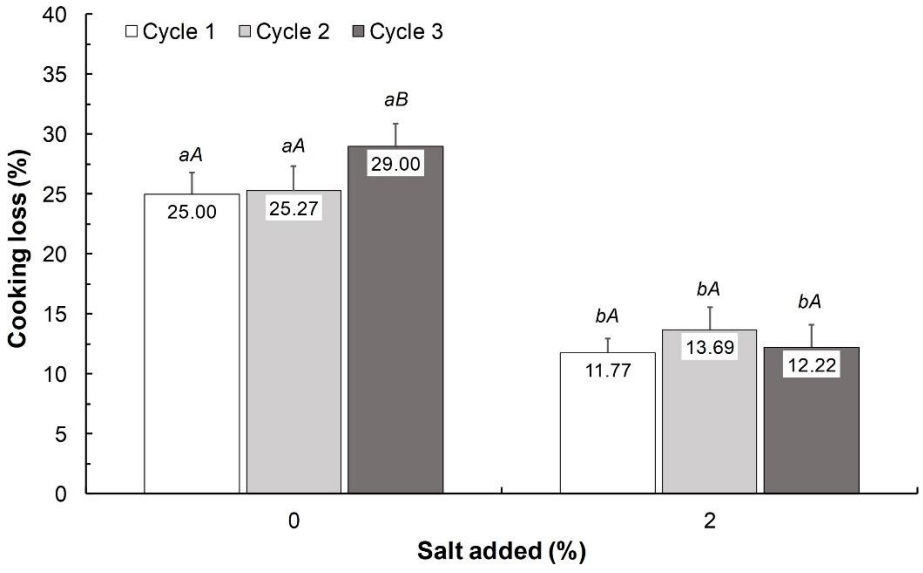

Fig. 1. Effects of salt (NaCl) x washing cycles interaction on cooking loss of turkey surimi-like gels. Bars (+ standard error of mean) with a common uppercase letters (*A-C*), for the same salt level, and lowercase letters (*a,b*), for the washing solutions or washing cycles, did not differ (*P>0.05*).

For washing solutions (Fig. 2), the cooking losses of surimi-like gels without salt added were lower (*P<0.05*) in samples washed by sodium bicarbonate (16.39 ± 2.75%), than washed with other solutions (mean of 29.77 ± 3.08%). In sol (added of 2% NaCl) gels, however, surimi-like obtained by washing with sodium bicarbonate (4.99 ± 1.45%) had lower (*P<0.05*) cooking loss than sodium chloride and phosphate buffer (13.28 ± 2.74%) and water washed samples (18.71 ± 23.91%). According to Massingue [4] the protein content was higher in TSL washed with water or sodium chloride (15.22%) than with phosphate buffer (14.15%) or sodium bicarbonate (12.35%). Therefore, the protein content did not appear to have been responsible for this difference. However, this author reported that samples washed with sodium bicarbonate has higher pH value and water holding capacity (WHC) than others surimi-like materials, being observed the inverse for water-washed samples, explaining the differences of cooking loss during gelation observed in this experiment.

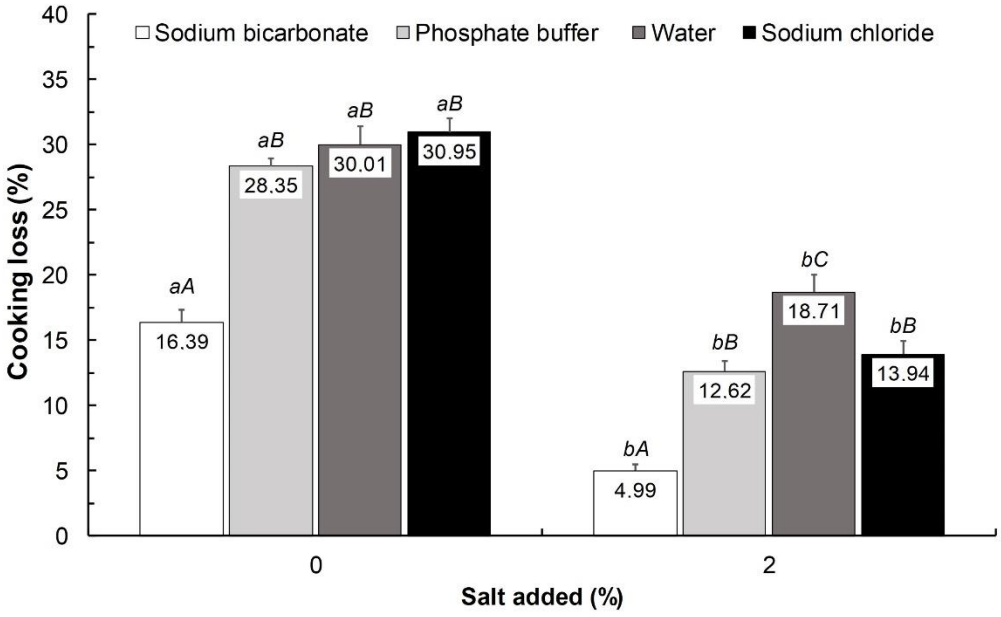

Fig. 2. Effects of salt (NaCl) x washed solutions interaction on cooking loss of turkey surimi-like gels. Bars (+ standard error of mean) with a common uppercase letters (*A-C*), for the same salt level, and lowercase letters (*a,b*), for the washing solutions or washing cycles, did not differ (*P>0.05*).

For the texture profile, there was a significant triple interaction between all factors for hardness, adhesiveness, and chewiness (Table 1). These interactions were decomposed and described in Table 2.

Overall, the hardness and chewiness of the heat-set gels were positively affected by salt addition. For both attributes the profile observed was like the cooking loss values, with samples that have higher cooking loss presenting higher hardness and chewiness values. Moreover, lower gel strength (lower hardness and chewiness) for sodium bicarbonate gels can be attributed to the high moisture and low protein content into the surimi-like material as previous reported [4]. The protein content is responsible for the hardness, as rheological parameters are strongly influenced by protein concentration in processed muscle foods [24]. Also, if the water content is too high, gels will be weak [14, 25]. These results agreed with previous reports concerning poultry surimi-like gel-forming [10, 12, 14]. Moreover, according with Ramadhan et al. [14], when washing increases the hardness, the values for chewiness were high as well.

Although hardness and chewiness from samples washed with sodium chloride, sodium bicarbonate, and phosphate buffer were not affected ($P>0.05$) by repeated washings when gelling without salt, they decreased ($P<0.05$) after three washing cycles when sol was prepared with 2% salt before gelling process. Otherwise, samples from water washed surimi-like presented a reduction ($P<0.05$) in the values of these attributes with washing cycles, independently of the addition of salt. These reductions were also related to the cooking loss values in samples cooked without salt, but not in the sol TSL samples. Ng and Huda [11] observed that increasing number of washing cycles with water, sodium bicarbonate, sodium chloride, and sodium phosphate buffer solutions increased hardness for duck surimi gel. However, Jin et al. [26] did not find differences between chicken surimi gel strength due to the repeated washings.

The adhesiveness increased ($P<0.05$) due to washing cycles for sodium chloride and sodium bicarbonate washed samples while water and phosphate did not ($P<0.05$) promote changes in adhesiveness. The most significant effect ($P<0.05$) of adhesiveness values was that observed for gels from sodium bicarbonate which increased mainly after two washes.

Table 2. Effects of a triple interaction (washing solutions x washing cycles x salt level) on hardness, adhesiveness and chewiness of turkey surimi-like gels.

Washing solutions	Washing cycles	Hardnes (N)		Adhesiveness (N×mm)		Chewiness (N×mm)	
		Without salt	2% salt	Without salt	2% salt	Without salt	2% salt
Water	1	51.05±1.44^{Aa}	71.66±5.06^{Ab}	0.08±0.03^{Aa}	0.05±0.01^{Aa}	640.47±59.51^{Aa}	880.01±36.98^{Ab}
	2	40.37±0.22^{Ba}	48.83±5.23^{Ba}	0.02±0.01^{Aa}	0.03±0.01^{Aa}	519.91±19.67^{Ba}	555.61±88.15^{Ba}
	3	27.22±9.13^{Ca}	35.69±3.17^{Ca}	0.08±0.02^{Aa}	0.04±0.03^{Aa}	260.85±42.57^{Ca}	373.57±36.28^{Ca}
NaCl	1	43.47±0.28^{Aa}	55.94±5.57^{Ab}	0.13±0.04^{Aa}	0.11±0.03^{Ab}	398.61±41.23^{Aa}	626.79±90.65^{Ab}
	2	36.18±3.02^{Ba}	55.85±2.08^{Ab}	0.10±0.01^{Aa}	0.11±0.02^{Ab}	359.32±44.48^{Aa}	660.91±39.25^{Ab}
	3	32.10±7.66^{Ba}	54.33±2.59^{Ab}	0.25±0.14^{Ba}	0.21±0.09^{Bb}	403.32±80.08^{Aa}	623.86±55.08^{Ab}
$NaHCO_3$	1	17.78±1.99^{Aa}	36.81±1.31^{Ab}	0.12±0.03^{Aa}	0.25±0.04^{Ab}	144.34±12.58^{Aa}	415.86±16.32^{Ab}
	2	14.74±3.27^{Aa}	41.18±7.76^{Ab}	0.25±0.04^{Ba}	0.55±0.19^{Bb}	132.96±18.10^{Aa}	434.52±96.52^{Bb}
	3	14.89±2.94^{Aa}	29.05±3.98^{Bb}	0.29±0.13^{Ba}	0.42±0.08^{Bb}	140.17±32.82^{Aa}	408.41±48.04^{ABb}
PO_4-buffer	1	30.88±3.54^{Aa}	49.78±8.86^{Ab}	0.03±0.02^{Aa}	0.10±0.03^{Aa}	297.14±40.40^{Aa}	470.59±0.09^{Ab}
	2	40.30±8.02^{Ba}	58.63±5.56^{ABb}	0.09±0.04^{Aa}	0.09±0.08^{Aa}	348.65±26.95^{Aa}	496.28±79.73^{Ab}
	3	37.44±5.38^{Ba}	60.68±3.64^{Bb}	0.05±0.01^{Aa}	0.05±0.01^{Aa}	271.23±12.90^{Aa}	617.09±76.34^{Bb}

NaCl = sodium chloride 0.086M; $NaHCO_3$ = sodium bicarbonate 0.06M; and PO_4-buffer = Phosphate buffer 0.04 M (pH 6.8).

$^{A-C}$Means with different superscript letter, within a column and for each washing solution, differ (*P>0.05*).

$^{a-b}$Means with different superscript letter, within a row and for each texture attribute, differ (*P>0.05*).

For cohesiveness (overall binding), an interaction between washing solutions and salt added was found. When salt was not added, cohesiveness of water-washed surimi-like gels (0.47 ± 0.04) were higher (*P<0.05*) than sodium chloride and phosphate buffer (0.40 ± 0.02) and sodium bicarbonate (0.36 ± 0.02) ones (Fig. 3). As observed for hardness and chewiness, this behavior was very similar to the cooking loss values (Fig. 2) and could be related to the protein content. However, when 2% salt was added, no difference (*P>0.05*) was observed between samples due to washing solution used (0.43±0.03). As describe above, by solubilizing the meat proteins, the salt improving the protein-protein binding [23] and, therefore, the cohesiveness of the batter.

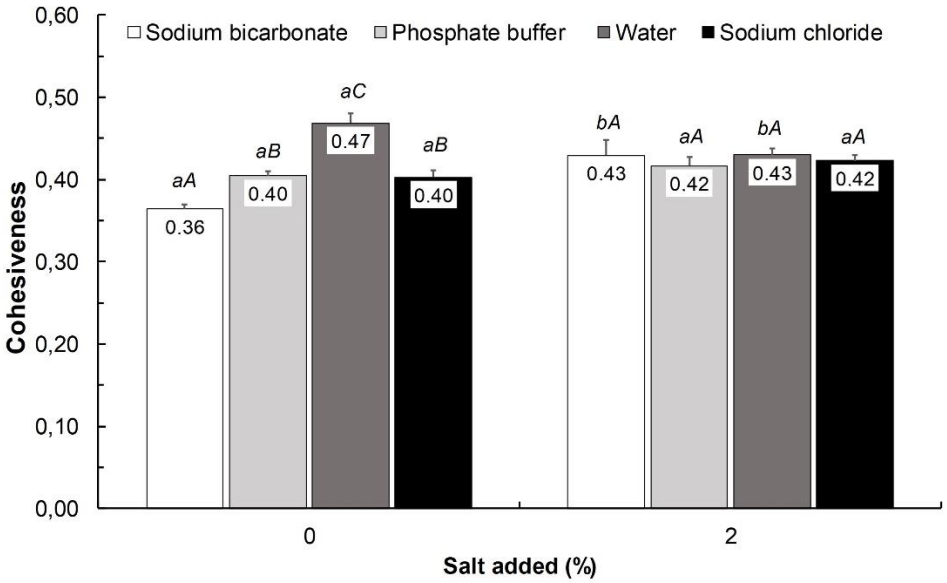

Fig. 3. Effects of salt (NaCl) x washed solutions interaction on cohesiveness of turkey surimi-like gels. Bars (+ standard error of mean) with a common uppercase letters (*A-C*), for the same salt level, and lowercase letters (*a,b*), for the washing solutions or washing cycles, did not differ (*P>0.05*).

The cohesiveness values were also affected (*P<0.05*) by washing cycles, increasing from the first to the third washes (Table 1). According to Pietrasik [27], the fat reduction causes an increase in cohesiveness values of meat products. This explains the increase in the cohesiveness

values, since a reduction in fat content of the turkey surimi-like was observed with higher washing cycles [4].

Springiness values were not affected ($P>0.05$) by the washing solutions or washing cycles (25.97 ± 1.51 mm). Contrary, Yang and Froning [10] found differences among gels as affected by washing solutions, in which water and sodium bicarbonate washed gels presented lower springiness. However, springiness had slightly enhanced ($P<0.05$) by salt addition (Table 1), as observed for the other texture attributes.

These facts confirm that reports from Park et al. [17] that the addition of NaCl at 1.5-3.0% improves gel strength properties of surimi-like from beef or pork. Moreover, because of the surimi high myofibrillar protein concentration, when mixed with salt and cooked, surimi forms a strong gel with an elastic, chewy texture. Salt improves the WHC of the meat proteins, promote protein destabilization and denaturation, and can cause protein aggregation prior to network formation during heat treatment [18], and could be predicted to improve gelation ability.

Heat-set gels microstructures

The scanning electron micrographs (SEM) of cooked turkey surimi-like gels from eight different types of extracted surimi-like material could be seen in Fig. 4. Structural changes of proteins during gel formation must allow for the development of a three-dimensional network that supports the formed gel. Added salt favored protein aggregation. This difference in salt concentration (0 and 2%) also seems to be the main factor for protein structural changes in the meat proteins. From SEM images, improvements in the network structure were observed with 2% added salt, which reflects in the gel strength (revealed by TPA parameters). The microstructure of myofibrillar proteins gelation was affected by ionic strength: at low ionic strength (gels without salt), fine-stranded gel structures were formed; at high ionic strength (gels with salt) coarsely aggregated gel structures were formed. Finally, could be observed the difference in the network gel of surimi-like material obtained by washing with sodium bicarbonate than others, especially in samples without salt, which reinforce the TPA differences found.

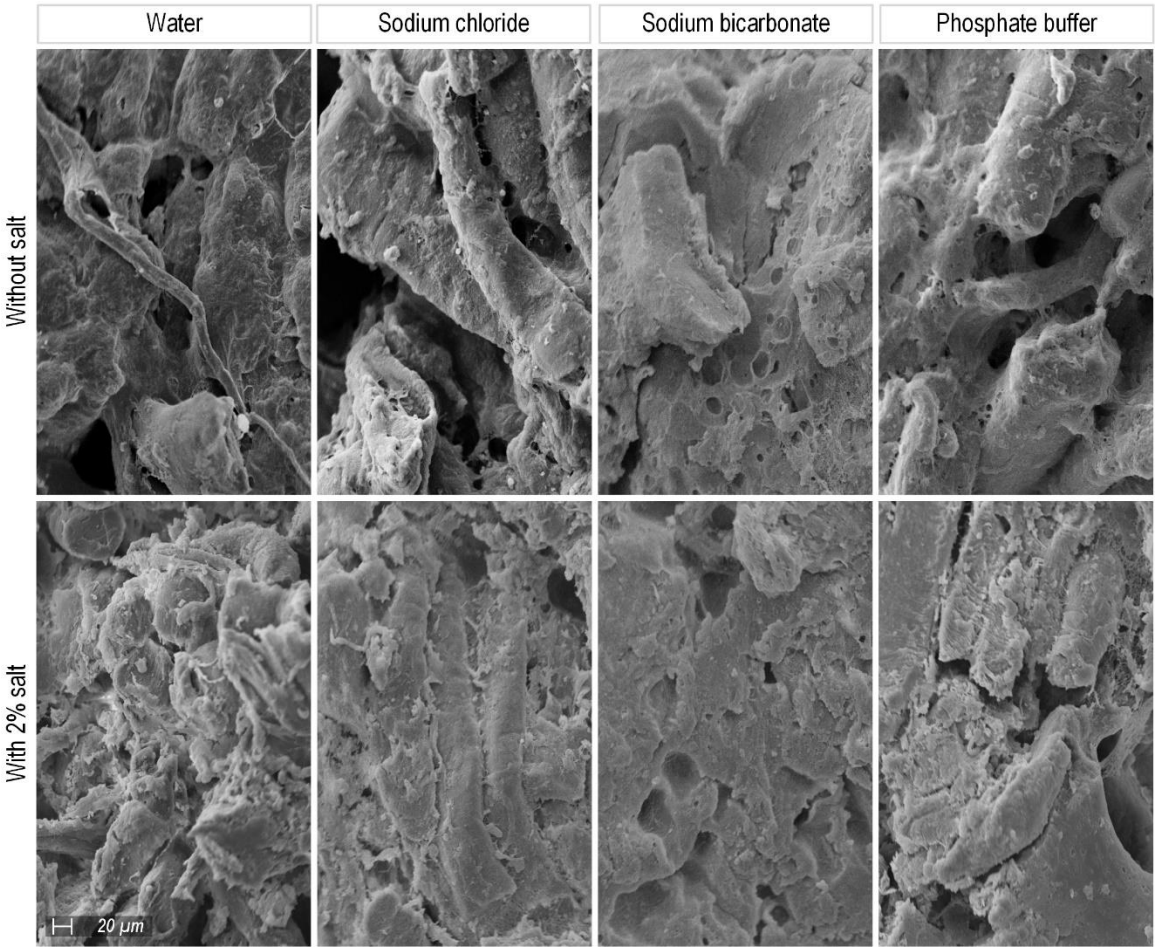

Fig. 4. Scanning electron micrographs (SEM; magnification 500x) of gels from turkey surimi-like washed by two cycles with water, sodium chloride (NaCl 0.086 M), sodium bicarbonate ($NaHCO_3$ 0.06 M), and potassium phosphate buffer (0.04 M; pH = 6.8), with (2%) or without salt (NaCl) addition.

Heat-set gels CIE color

Fig. 5 illustrate the color of het-set gels of TSL obtained from MDTM by different washing solutions after two washing cycles. Overall, the perceptible differences in the color of gels confirms the differences observed previously [4] in the color of protein concentrate (TSL) after different washed cycles and solutions. As can see by the pictures, sodium bicarbonate followed by phosphate buffer washed samples were lighter (higher L^* values) and whiter (higher whiteness values) colored material, being more yellowish (higher h values) but with less intense (lower C^* values) color than other samples. These should be related to the highest heme pigment

removing during the washing process during elaboration of TSL, particularly when sodium bicarbonate was used. According to Jin et al. [26] lightness and whiteness are particularly important quality attributes of surimi.

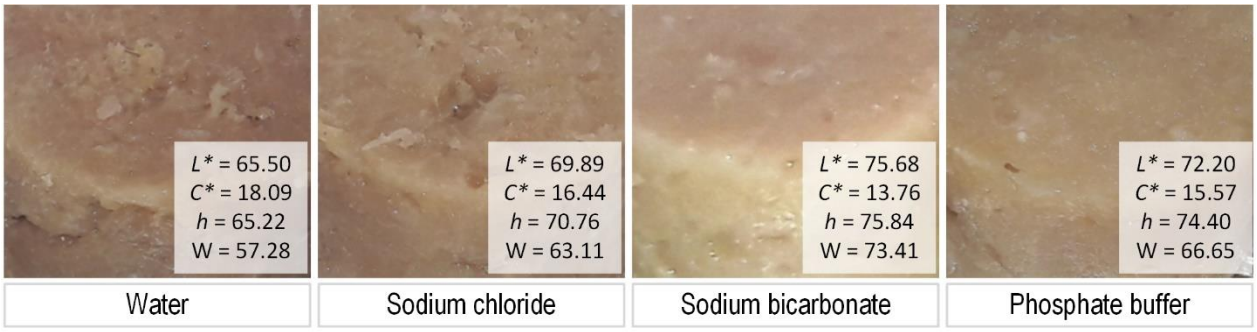

Fig. 5. Pictures and CIELCH values of gels from turkey surimi-like washed two cycles with water, sodium chloride (NaCl 0.086 M), sodium bicarbonate ($NaHCO_3$ 0.06 M), and potassium phosphate buffer (0.04 M; pH = 6.8). *L** = lightness; *C** = chroma; *h* (graus) = hue angle; and W = whiteness.

CONCLUSIONS

The use of water, sodium chloride (NaCl), sodium bicarbonate ($NaHCO_3$) and potassium phosphate buffer in surimi-like materials (TSL) obtained by washing of the mechanically deboned turkey meat presented different effects on the gel properties. Preparing TSL sol (addition of 2% salt) before gelling process improved the gel's overall texture. Washing with $NaHCO_3$ reduced the gel strength but implied in lower cooking loss and in lighter colorless material. Thus, it was noted that the use of $NaHCO_3$ solution with two washes cycle could be a potential alternative to obtain TSL with proper textural properties to be used in the manufacture of surimi-based foodstuff, such as poultry meat products.

ACKNOWLEDGEMENTS

The author would like to thank the Brazilian funding agencies: Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq; 430206/2016-0) and the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG; CVZ APQ-02015-15 and CVZ

APQ-02904-17) for their financial support. The author also grateful to the Government of Mozambique and to the Brazilian agency Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the scholarship granting (Doctorate Degree) by the Programa de Estudantes-Convênio de Pós-Graduação (PEC-PG/CAPES).

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ARTICLE 3

Article drafted in accordance with the Meat Science journal standard
"Preliminary version"

Technological and sensorial characteristics of ready-to-eat broiler breast elaborated with surimi-like material from mechanically deboned turkey meat

Abstract

The purpose of this study was to evaluate the effects of the partial replacement of poultry meat by turkey surimi-like material (30% and 60% TSL) or mechanically deboned turkey meat (30% MDTM) on technological and sensory properties of ready-to-eat restructured broiler breast. Addition of MDTM and TSL reduce protein content and lightness (lower L^* values) and increase calcium content and hardness, chewiness and springiness values. Broiler breast with MDTM was redder (lower h values) and had higher fat content and lipid oxidation (higher TBARS values) than other treatments. The use of TSL maintain the low-fat content of the control, but additions of 60% TSL increase moisture and sodium content, syneresis and h values (being yellower) and compromised their sensorial acceptance. Addition of 30% TSL resulted in less alteration compared to the control and retains the light color and soft flavor characteristics of poultry meat. Therefore, 30% TSL could be used as partial substitute of broiler breast meat to develop poultry products with high-quality technologic and sensory characteristics.

Keywords: Low-fat meat product; Surimi-like material; Physicochemical properties; Sensory profile; Microstructure.

1 Introduction

Restructured or comminuted cooked meat products are a diverse group of foods prepared with ground meats, added salt and spices and have evolved over the centuries into a unique range of muscle-based foods (Murphy, Gilroy, Kerry, Buckley, & Kerry, 2004). This type of product is widely explored in Brazil since decade of 1990 driven by the higher poultry production (Dikeman & Devine, 2004) accompanied by high demand from noble cut-up and processed poultry meat. Thereafter, a large amount of low valued meat from necks, backs, thighs and drum-sticks is produced, being used for mechanically deboned meat (MDM) production. Due to its low cost, the MDM is one of the several ingredients used in the food industries as a muscle food substitute in manufacturing of restructured or comminuted meat products (Mielnik, Aaby, Rolfsen, Ellekjær, & Nilsson, 2002). Preparation of MDM enables a more economical use of animal products and reduction of the amount of biological wastes (Püssa et al., 2009).

Since special and industrialized cuts are products that drive the expansion of poultry consumption, this has demanded adjustments from the poultry industry for the development of ready-to-eat meat products that are easy to prepare and that meet consumer requirements while offering attractive prices compared to other types of meat (Almeida et al. 2015). However, the use of MDM in meat products has limitations due to its oxidative susceptibility, intense flavor, reddish dark color, undesired textural properties and perishability (Pereira et al., 2011; Massingue et al., 2018). Moreover, besides lipid oxidation, changes in color and flavor are the main concerns of using MDM in poultry meat products, since they have a milder flavor and less intense coloration than pork or beef products.

To overcome the undesirable characteristic of MDM, the surimi processing has been used to promote added-value of this raw material (Ramadhan, 2014; Ismail et al., 2011; Massingue, 2018a), generating products known as “surimi-like” when it was not obtained from fish (Tina et al. 2010). This process involves washing the meat with water or weak strength ionic salt solutions several times, removing fats and pigments and concentrating myofibrillar proteins, in order to obtain a colorless material with good technological properties, lower fat content and long shelf-life (Stangierski, 2013; Cortez-Vega et al., 2013). The surimi-like material possesses some important functional properties such as gel forming ability and water holding capacity due to its content of myofibrillar proteins, which are mainly responsible for gel and emulsion forming as

act to stabilize the comminuted and restructured meat products (Tina et al., 2010; Massingue, 2018b). However, the characteristics and functional properties of surimi-like material can vary depending on the meat source, and it is featured raw material for meat products production due to its high practical use favored by the low cost.

A few studies concerning low-reduced fat meat products made using surimi and surimi-like from several meat sources and described in the literature could be found. Among of these studies are: patties or burgers using surimi-like from turkey MDM and breast (Hernandez; Baker, & Hotchkiss, 1986); duck MDM (Ramadhan, Huda, & Ahmad, 2012) and pork (Choi et al, 2012); sausages with surimi-like from chicken MDM (Cortez-Vega et al., 2013), pork MDM (Wimmer, Sebranek, & McKeith, 1993), beef heart (Desmond & Kenny, 1998) and fish surimi (Cortez-Vega et al., 2013; Murphy et al., 2004; Cavestany et al, 1994); and crab sticks (Jin et al., 2009) and *Kamaboko* (Cortez Vega, Pizato, & Prentice, 2014) made with chicken surimi-like. However, little information exists on how to increase the maximum allowable level of surimi-like to prepare acceptable poultry products, particularly in cooked ham-type products.

Of our knowledge, no study evaluated the effects of surimi-like from turkey as meat substitute in the quality of processed poultry products. Previous experiments (Massingue 2018a; 2018b) describes the development of surimi-like materials from mechanically deboned turkey meat (MDTM) with higher quality properties for further utilization in the manufacture of low-fat meat products. Therefore, the goal of this study was to evaluate the effects of surimi-like material from MDTM on technological and sensory characteristics of a low-fat ready-to-eat restructured broiler breast, determining the meat replacement level that produced the highest consumer acceptability.

2 Material and Methods

2.1 Raw meat material

Frozen mechanically deboned turkey meat (MDTM) were donated by BRF® Brazil (Jundiaí, São Paulo, Brazil), transported to the Laboratory of Meat Science and Technology (LabCarnes) on the Food Science Department of Federal University of Lavras (UFLA) and kept stored (-20 ^{o}C) until surimi-like processing (less than two weeks). The frozen broiler breast meat

was bought at the local market of Lavras, Minas Gerais. The MDTM and broiler breast raw material were analyzed for proximate composition; sodium and calcium contents; pH, water activity, lipid oxidation (TBARS test) and instrumental color.

2.2 Turkey surimi-like material production

The turkey surimi-like (TSL) material used as ingredient in the present work was obtained using 0.06 M sodium bicarbonate solution ($NaHCO_3$) as suggested by Massingue (2018a; 2018b) to manufacture poultry products. According to these authors, two cycles of MDTM washing with this solution lead to a low-fat whitish and flavorless surimi-like material, with high water holding capacity and low cooking loss during gel formation.

The TSL obtention followed the procedure described by Massing (2018a). The frozen MTDM was thawed in 4 volumes of cold (4 ^{o}C) washing solution ($NaHCO_3$ 0.06 M) and homogenized using a propeller shaft agitator (model RW20; IKA Ltd., Brazil), at 220 rpm for 10 min. The upper layer of fat was removed using a stainless-steel skimmer and the slurry filtered and pressed in cheese cloth to remove excess water. The remaining residue was resuspended with 4 volumes of the original wash solution, homogenized (220 rpm/10min) and filtered and pressed again in cheese cloth. The second residue was used as TSL in this experiment.

For each repetition (products batch), the TSL material was obtained and stored at 4 ^{o}C for no longer than 3 h before use. The average production yield was approximately 35% of recovery protein concentrate. As raw material, the surimi-like was also submitted for proximate composition; sodium and calcium contents; pH, water activity, lipid oxidation by the TBARS test; and, instrumental color analyses.

2.3 Ready-to-eat broiler breast formulation and processing

The poultry meat product used this study was the restructured, cured and cooked broiler breast, commercially available in Brazil. This product had reduced levels of fat and high protein content associated with a milder flavor, so the evaluation of meat substitution by TSL seemed appropriate.

Four different formulations of ready-to-eat broiler breast were prepared using TSL or MDTM as broiler breast meat replacer (Table 1). The broiler breast meat was initially ground through a 16 mm plate grinder (Beccaro PB-22 model, SP, Brazil) and mixed with the ingredients by 10 min. The batter was stuffed (EP-5 model; Picelli, Rio Claro, SP, Brazil) into polyamide artificial casing (67-mm diameter; Spel®, SP, Brazil), to produce products with approximately 500 g, and clipped at both ends (MGE polyclip system MLE-300 model, SP, Brazil). Then, they were subjected to a water bath cooking, following a previously established cooking set-up to reach the internal temperature of 72 °C (measured by a thermopar inserted into the core of the product). When the endpoint temperature was achieved, the products were immediately chilled on ice water-bath for 30 min and stored (at 4 °C) until further analysis (at 1, 30 and 60-days). Three independent repetitions of each batch were prepared.

Table 1 Formulations (%) of ready-to-eat poultry product manufactured with mechanically deboned turkey meat (MDTM) or turkey surimi-like (TSL) in substitution of broiler breast meat.

Ingredients	**CONT**	**MDTM**	**TSL30**	**TSL60**
Broiler breast	70.0	49.0	49.0	28.0
TSL	-	-	21.0	42.0
MDTM	-	21.0	-	-
Ice water	23.4	23.4	23.4	23.4
Mix of ingredients*	6.6	6.6	6.6	6.6

* 2% salt (NaCl); 2% cassava starch; 1% isolate soy protein; 0.5% sugar; 0.5% sodium polyphosphate; 0.3% carrageenan; 0.2% monosodium glutamate; 0.02% sodium nitrite; 0.05% sodium erythorbate; and 0.03% seasoning. CONT = control without TSL and MDTM; MDTM = 30% of MDTM as substitution of broiler breast meat; and TSL30 and TSL60 = products containing 30 and 60% of TSL as substitution of broiler breast meat.

2.4 Chemical composition and physicochemical analysis

Following the standard procedures of Association Analytical Chemists (AOAC, 2005), proximate composition (%) of raw meat material (broiler breast, MDTM and TSL) and finished products (24h post-cooking) were analyzed in triplicate by measuring the total moisture (AOAC 950.46B, 105 °C oven air-drying method), fat (AOAC 960.39, ether extractable component), protein (AOAC 981.10, Kjeldahl nitrogen method using 6.25 as conversion factor) and ash

(AOAC 950.46, 500 °C muffle furnace) contents. The minerals sodium (mg/100g) and calcium (% on dry matter basis - DMB) were also determined by the Atomic Absorption Spectrophotometry Method (AOAC 975.03) after dry ashing sampling preparation.

Analyzes of pH, water activity and TBARS index were conducted on the finished products during the storage time at 4 °C at 1, 30 and 60 days. The pH was measured in three different points of the samples by using a digital pH meter (Digimed model DM20, SP, Brazil) equipped with a puncture glass electrode. The water activity was determined in triplicate by using an Aqualab® CX2 (Decagon Devices Inc., Washington, USA) hygrometer. The degree of lipid oxidation in the products was assessed in triplicate by measuring the 2-thiobarbituric acid reactive substances (TBARS index) according to the methodology proposed by Jo and Ahn (1998), with minor modifications. Five grams of minced sample was homogenized (Turratec TE-102, Tecnal®, Brazil) with 50 mL of chilled distilled water (4°C) and 100µL 7.2% butylated hydroxytoluene (BHT) for 15 s at 14,000 RPM. An aliquot of 1 mL of homogenate was then added of 2 mL of TBA/TCA reactive solution (20 mM 2-thiobarbituric acid in 15% trichloroacetic acid, w/v) and heated in boiling water-bath for exactly 15 min. After cooling in an ice water bath, tubes were centrifuged (Hettich Zentrifugen EBA 21, Germany) at 3,000*g* for 15 min and the absorbance (at 532 nm) read in a Thermo spectronic spectrophotometer (Spectronic Genesys 10 UV-Vis, Germany). The concentration of malonaldehyde (MDA) was determined using 1.56×10^5/M/cm as the extinction coefficient of the pink TBA chromagen (Sinnhuber and Yu, 1958), and the TBARS values were expressed as mg MDA/kg of sample.

For syneresis analysis, 1-mm slices of the products were obtained (USM2, Brazil), vacuum-packaged (R. Baião BD420, Brazil) and stored for 30 and 60 days at 4°C. Syneresis was calculated as a result of the liquid exudate from a sample during storage periods and was expressed as a percentage of an initial weight of the sample.

2.5 Instrumental color and texture analyzes

Products were tested by instrumental color at days 1 (24h post-cooking), 30 and 60 of storage, using a Minolta CM-700 (Konica Sensing Inc, Osaka, Japan) colorimeter. For texture, samples were tested by Texture Profile Analysis (TPA) method at the day 1, using a universal

Texture Analyzer TA.XT2i (Stable Micro Systems Ltd., England), as described by Ramos and Gomide (2017).

The instrumental color was determined by the CIELAB system with a D65 standard illuminant, an observer angle of 10°, aperture of 8 mm and specular component excluded (SCE) mode. The products were sliced in half and six measurements representing the entire internal cross-section surface were taken from each sample. Lightness (L^*), redness (a^*) and yellowness (b^*) were recorded. The angular coordinates of chroma (C^*) and hue angle (h, graus) were calculated using the following formulas: $C^* = (a^{*2} + b^{*2})^{1/2}$ and h = arctan (b^*/a^*). Higher C^* values suggest more vivid color, and h values near 0 are red and near 90° are yellow.

For the TPA test, 5 cubes (with 10 mm edge) were obtained and compressed twice to 60% of their original height, at room temperature, with compression flat cylindrical aluminum probe (36 mm diameter). A cross-head speed of 180 mm/min was applied and there was no rest time between the two cycles of compression. Force time curves were recorded during compression and five texture attributes were calculated as follows: 1) hardness (N), peak force required for the first compression; 2) springiness (mm), distance sample recovers after the first compression; 3) adhesiveness (N mm), the negative force area for the first bite representing the work necessary to pull the compressing plunger away from the sample; 4) cohesiveness, the ratio of positive force area during the second compression to that in the first compression; and 5) chewiness (N mm), the product of hardness, cohesiveness, and springiness.

2.6 Microstructure

Structural analysis was carried out at day 1 (24h post-cooking) to correlate the sensory available texture and the matrix dimension of the finished products. The samples were evaluated microstructure over the light microscope using hematoxylin and eosin (H&E) staining method, and by the scanning electron microscope (SEM). Three replicates of the samples were carried out for the analysis,

For H&E staining, cubes of 0.5 cm length of each sample were fixed in the neutral buffered formaldehyde (NBF) solution and processed to optical view as described by Groelz et al. (2013). Sections of 4 μm thickness from the samples pattern paraffin-embedded tissue blocks were cut on a microtome (MRP09, Lupe Tec-applied technology, São Carlos, Brazil), stretched for 1 min on a

water bath (40 ºC, filled with fresh, deionized water), placed on slides and air-dried overnight at room temperature. Staining was performed manually in staining dishes starting with a de-waxing step in xylene, then rehydration with successive incubations in 100%, 95%, 85%, 70% ethanol, and finally water. Hematoxylin (Sigma-Aldrich Co., D. Caxias, RJ, Brazil) was applied for 1 min followed by a 3 min wash with water then followed by staining for 1 min with eosin (Sigma-Aldrich Co., D. Caxias, RJ, Brazil). After washing with water and dehydration with successive washes of 85%, 95%, 100% ethanol, and xylene, slides were mounted with coverslips and air-dried prior to microscopic examination.

For SEM analysis, samples were prepared as described by Bozzola and Russel (1999). Cubes of 0.5 cm length were fixed in Karnovsky's Fixative (buffer solution of sodium cacodylate 0.05M, $CaCl_2$ 0.001M, pH 7.2 with 2.5% paraformaldehyde 2.0% glutaraldehyde) at 4 ^{o}C for 24h. After fixation, samples were dehydrated for 10 min into a series of 25%, 50%, 75% and 90% acetone (acetone/water, v/v) and three times for 10 min into 100% acetone. Samples dehydration was completed by the critical point drying a CPD 030 device (BAL-TEC AG, Balzer, Germany), coated with gold using *sputtering* SCD 050 device (BAL-TEC AG, Balzer, Germany) and observed in a Scanning Electron Microscope LEO EVO 40 (Carl Zeiss, Germany) at 15.02 kV and at a working distance of 7.5 mm. The images were scanned and digitalized using software CorelDRAW® X8, São Paulo, Brazil.

2.7 Microbiological evaluation

Populations of target microbial groups including coliforms, *Clostridium* sulphite reductants, lactic acid bacteria (LAB), aerobic mesophilic and psychrotrophic were monitored in sliced vacuum-packaged products at day 1 (24hrs post-cooking), 30 and 60 days of storage (4°C). Twenty-five grams of samples were added 225mL of sterile peptone water 0.1% (w/v) and homogenized in a Stomacher (MetrotermR, Brazil) with 490 strokes/2min at room temperature. Stomached slurries were decimally serially diluted into peptone water and plated under the following conditions according to the method described by Vanderzant and Splittstoesser (1992): thermotolerant coliforms bacteria were monitored by three serial tubes gas production in Bright Green Broth Bile 2% at 35^{o}C/24-48 h; sulphite-reducing *Clostridium* were determined in Sulphite Polimixine Sulphadiazine Agar at 46^{o}C/24h under anaerobiosis; psychrotrophic bacteria were

determined in Plate Count Agar (PCA) at 7°C/10 days incubation; LAB in de Man Rogosa and Sharpe Agar at 32°C/48h; and aerobic mesophilic bacteria in PCA at 37°C/48hs.

2.8 Sensory evaluation

Sensory analysis was performed at 1 week of storage at the Federal University of Lavras (UFLA) after approval by the National Research Ethics System (SISNEP, Brazil) under protocol CAAE 30844314.5.0000.5148, conforming to resolution number 196/96 of National Health Council (Brasil, 1996).

To describe the sensory characterization of each product formulated, the check-all-that-apply (CATA) questionnaires have evaluated according to Jorge et al. (2015). First, the CATA terms were defined by 13 untrained participants consisted of the LabCarnes undergraduate and graduate students. All participants were frequent consumers (more than twice per week) of restructured cooked ham type products. All samples were cut into cubes of approximately 20 mm edge and were presented in a single testing session (Repertory Grid technique), wherein judges used an open-ended question for establishing the appropriate terms for describing their appearance, flavor, and texture. The most mentioned terms for each attribute were chosen to compose the CATA questionnaires (Table 2).

Table 2. Terms surveyed for check-all-that-apply (CATA) questions of each sensory attribute.

Appearance	Flavor	Texture
Glossy appearance	Broiler taste	Firm texture
Homogenous appearance	Turkey taste	Soft texture
Porous	Rancid taste	Consistent
Light color	Bitter aftertaste	Rubbery texture
Dark color	Soft flavor	Gelatinous
Brown color	Salty taste	

In the second stage, 55 untrained consumers, consisted of professors, undergraduate and graduate students, 14 males and 41 females, ages ranging between 18 and 60 years, were randomly recruited. All participants declared to be consumers of restructured cooked ham type products. The sensory analysis was performed in a single testing session conducted in individual

cabins with white light. Cubes of approximately 20 mm edge were labeled with a 3-digit code and were presented to the panelist in a randomly, balanced and monadic sequence. Drinking water was provided to the panelists so they could clean their palate between sample trials. The panelists received the sensory evaluation form (acceptance test) and evaluated the samples using a 9-point hedonic scale (1 = "disliked extremely"; 5 = "neither liked/disliked"; and 9 = "liked extremely") for each attribute (appearance, flavor, texture and overall impression). In the same form, the panelists were asked to check all the terms of CATA questions (as previously defined, Table 2) that considered appropriate to describe each attribute.

2.9 Statistical analysis

The experiment was conducted in a completely randomized design, in a split-plot scheme, with the four treatments (CONT, MDTM, TSL30 and TSL60) in the plot and the three-storage time (1, 30 and 60-days) in the split-plot (except for raw material analysis and for proximate composition and texture profile analysis of the products which were not evaluated during the storage time), with three repetitions (batches). Effects of formulation, storage time and their interaction were evaluated by ANOVA and, when necessary, by Duncan test using software SAS 9.2 (SAS Institute Inc., Cary, NC, USA) package, with significant level of 5% (α=0.05).

For sensorial attributes, a statistical analysis was performed by assuming a randomized block design, wherein each consumer represented a block for CATA acceptance. The effect of formulation was evaluated by ANOVA and, when necessary, by Duncan test. Also, each attribute was analyzed individually with an internal preference mapping (IPM), which analyses hedonic ratings by judges for a product set by principal component analysis (PCA) of the covariance matrix and provides a summary of the main preference directions. While PCA does not filter out variables, this IPM tool allows removing from the plots the judges that are not well enough displayed-on a given two-dimensional map. Consumer's data of appearance, flavor, and texture were also simultaneously analyzed by a three-way internal preference map (IPM tri-plot), which is also known as parallel factor analysis (PARAFAC), according to Nunes, Pinheiro, & Bastos (2011).

To identify the relationships between the CATA terms selected for each sample, an external preference map (EPM) was finally used. In EPM the analysis was based on the regression of

external descriptors against consumer data (overall impression in this case) for each consumer. According to Elmore et al. (1999), models with less than 30% of significance could be considered valid to generate the EPM graphic, so only the slopes for consumers that provided valid models ($P \leq 0.30$) were plotted on the map.

Finally, PCA graphs was conducted to correlate the instrumental color and texture parameter with the sensory attributes of the CATA test. PCA, IPM and EPM analyses were performed in the SensoMaker statistical software package (Lavras, Brazil), version 1.5.

3 Results and Discussion

3.1 Raw material characteristics

The chemical composition and the physicochemical characteristics of the raw material used to manufacture the ready-to-eat products are shown in Table 3.

Table 3. Quality characteristics (means ± standard deviation) of the raw material used to manufacture the ready-to-eat broiler breast

Characteristics	**Raw material**			***Pr>F*[1]**
	Broiler breast	**MDTM**	**TSL**	
Protein (%)	21.30 ± 1.00[a]	14.08 ± 0.81[b]	13.82 ± 1.51[b]	***<0.001***
Moisture (%)	75.07 ± 0.29[a]	57.97 ± 1.09[b]	78.94 ± 0.15[c]	***<0.001***
Fat (%)	2.41 ± 0.57[a]	25.80 ± 1.83[b]	2.53 ± 1.31[a]	***<0.001***
Ash (%)	1.10 ± 0.003[a]	1.10 ± 0.03[a]	0.72 ± 0.02[b]	***<0.001***
Sodium (mg/100g)	41.06±0.46[a]	57.55±3.20[a]	105.31±7.69[b]	***0.007***
Calcium (%, DMB)	0.05±0.01[a]	1,44±0.11[b]	1,97±0.13[c]	***0.001***
pH	5.95 ± 0.11[a]	6.42 ± 0.01[b]	7.99 ± 0.17[c]	***<0.001***
Lightness (*L**)	59.97 ± 6.48	56.79 ± 2.41	65.35 ± 0.73	*0.990*
Redness (*a**)	1.72 ± 1.26[a]	11.53 ± 1.58[b]	1.84 ± 2.29[a]	***<0.001***
Yellowness (*b**)	16.69 ± 1.93	18.31 ± 1.96	17.46 ± 2.47	*0.148*
Chroma (*C**)	16.81 ± 1.99[a]	21.67 ± 2.06[b]	17.65 ± 2.61[a]	***0.018***
Hue angle (*h*, graus)	84.24 ± 3.87[a]	57.77 ± 3.96[b]	80.52 ± 1.37[a]	***<0.001***

MDTM = mechanically deboned turkey meat; TSL = turkey surimi-like; and DMB = dry matter basis; [1]Significant probabilities (*P<0.05*) were placed in bold.
[a-c]Means with different superscripts within a row are different (*P<0.05*).

Washing procedure reduced ($P<0.05$) the fat content and chroma (C^*) and increased ($P<0.05$) moisture and minerals sodium and calcium contents and hue angle (h), while protein content (mean of 13.95 ± 1.09%) and lightness (L^* = 61.07 ± 4.95) did not differ ($P>0.05$) between MDTM and TSL material. These characteristics were also observed by Massingue (2018a) when evaluating the TSL obtained whith the same washing procedure.

3.2 Products composition and physicochemical characteristics

The formulations were different ($P<0.05$) with respect to their levels of moisture, fat, protein and ash (Table 4). Overall, the use of TSL or MDTM as substitute of broiler breast meat provides a reduction ($P<0.05$) on the protein content and an increase ($P<0.05$) in the ash content. Only 60% replacement of broiler breast with TSL implied a slight increase in the moisture in relation to control sample. Fat content was higher ($P<0.05$) in only the treatment added to MDTM than all others. Processed meat product containing high amounts of TSL can be expected a slight decrease of fat and protein contents, and an increase of moisture due to the TSL composition.

Regarding the proximate composition, all treatments, including the control, were within the limits established by the Brazilian legislation (Brasil, 2000) only for protein content (minimum of 12%), but without the law on the maximum amount of moisture (maximum of 70%). The fat content in foods according to the Brazilian legislation (Brasil, 2012), indicates a product can receive the “low-fat” label only if it holds less than 3% of fat. Hence, the use of TSL as MDTM substitute ensures a “low-fat” label due to the reduced- and low-fat final products compared to that containing MDTM. This is a great advance for the use TSL in food. Choi et al. (2012) demonstrated that the use of at less 20% of porcine muscle surimi-like in pork patties as back-fat replacer got the most to produce a low-fat meat product (1.76±0.34 grams of fat per 100 grams of the sample).

Calcium and sodium contents are also given in Table 4. Calcium content was higher ($P<0.05$) due the replacement of broiler breast with 30% or 60% TSL into formulation and greater than the maximum limit of 0.45% determined by the Brazilian legislation (Brasil, 2000). Sodium content was different among treatments ($P<0.05$), being the highest value observed ($P<0.05$) in treatment containing high amounts of added surimi-like (TSL60).

Table 4. Proximate composition and mineral content (means ± standard deviation) of the ready-to-eat broiler breast

Characteristics	Formulations				*Pr>F*[1]
	CONT	MDTM	TSL30	TSL60	
Protein (%)	19.96 ± 0.86[a]	17.06 ± 0.60[b]	17.76 ± 0.45[b]	15.90 ± 0.71[c]	***0.001***
Moisture (%)	76.19 ± 0.46[a]	74.15 ± 0.19[b]	77.91 ± 1.11[ab]	79.37 ± 1.66[c]	***0.001***
Fat (%)	1.46 ± 0.33[a]	3.64 ± 0.23[b]	1.25 ± 0.64[a]	1.96 ± 0.23[a]	***<0.001***
Ash (%)	2.57 ± 0.22[a]	3.25 ± 0.04[b]	3.48 ± 0.36[b]	3.32 ± 0.05[b]	***0.007***
Sodium (mg/100g)	583.23 ± 8.46[a]	623.88 ± 52,50[a]	593.85 ± 14.28[a]	759.18 ± 33.14 [b]	***0.016***
Calcium (%, DMB)	0.09 ± 0.01[a]	0.31 ± 0.06[b]	0.65 ± 0.11[c]	0.89 ± 0.13[c]	***0.020***

CONT = control without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM = 30% of MDTM as substitution of broiler breast meat; TSL30 and TSL60 = products containing 30 and 60% of TSL as substitution of broiler breast meat; and DMB = dry matter basis.

[1]Significant probabilities (*P<0.05*) were placed in bold.

[a-c]Means with different superscripts within a row are different (*P<0.05*).

According to the Food Standards Agency (FSA, 2017) low-sodium ham or other cured meat products should have a maximum of 650 mg/100 g of sodium, higher value than that observed in the other treatments (CONT, MDTM and TSL30). The increasing sodium content in TSL60 could be due to the sodium bicarbonate washing treatment that allowed residual sodium target during surimi production. Moreover, for the Brazilian legislation (Brasil, 2012), all treatments contain more than 80 mg of sodium per 100 g sample are without of low-sodium concept for the low-sodium foods.

The results of the physicochemical characteristics of the ready-to-eat breast as affected by the different treatments and storage time are presented in Table 5.

Table 5. Effects of treatment (T) and cold storage (S) on physicochemical characteristics (means ± standard deviation) of ready-to-eat broiler breast.

Effect	**Source of variation**	**pH**	**Aw**	**Syneresis (%)**	**TBARS values (mg/Kg)**
Treatment (T)	CONT	5.96 ± 0.32^{a}	0.973 ± 0.001^{a}	2.96 ± 2.26	0.24 ± 0.18^{a}
	MDTM	6.09 ± 0.28^{a}	0.971 ± 0.002^{b}	4.22 ± 3.31	0.71 ± 0.14^{b}
	TSL30	6.11 ± 0.38^{a}	0.974 ± 0.003^{a}	3.94 ± 3.15	0.31 ± 0.09^{a}
	TSL60	6.42 ± 0.25^{b}	0.976 ± 0.002^{c}	5.81 ± 4.46	0.56 ± 0.18^{b}
Storage periods, days (D)	0	6.48 ± 0.15^{a}	0.974 ± 0.002^{a}	0.00 ± 0.00	0.46 ± 0.22
	30	6.11 ± 0.25^{b}	0.975 ± 0.002^{a}	5.94 ± 2.12	0.49 ± 0.27
	60	5.85 ± 0.26^{c}	0.972 ± 0.002^{b}	6.77 ± 1.61	0.41 ± 0.25
Pr>F[1]	T	***0.007***	***<0.001***	***<0.001***	***0.007***
	D	***<0.001***	***0.001***	***<0.001***	*0.257*
	T x D	*0.699*	*0.177*	***<0.001***	*0.892*

CONT = control turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); TSL30 and TSL60 = products containing 30 and 60% of TSL as substitution of broiler breast meat; and MDTM = 30% of MDTM as substitution of broiler breast meat.

[1]Significant probabilities ($P<0.05$) were placed in bold.

[a-c]Means with different superscripts within a column are different ($P<0.05$).

Replacements of 30% of broiler breast by TSL or MDTM did not change ($P>0.05$) the pH values. However, samples with 60% TSL presented higher pH values ($P<0.05$) than the others, due to the high pH value of this raw material. Higher pH values in products formulated with a

high amount of surimi-like material were also reported by other authors (Wimmer et al., 1993; Jin et al., 2009). However, during the storage time the pH values decreased (*P<0.05*), which could be due to increase of lactic acid content caused by the acid lactic bacteria growth (item 3.5).

The water activity (Aw) was also affected (*P<0.05*) by the treatments and storage time. Treatment with 60% TSL had higher (*P<0.05*) and with MDTM had lower (*P<0.05*) water activity than treatments control and TSL30. However, all Aw are high over than 0.970. Rocland and Nishi (1980) reported that water activity has a closer relationship to the chemical, physical, and biological properties of foods. In fact, the Aw values of the products appear to be closely related to the moisture values of the added raw materials; more precisely with the moisture / protein ratio.

The water loss during storage (syneresis) was affected (*P<0.05*) by interaction between treatments and storage time (Fig. 1).

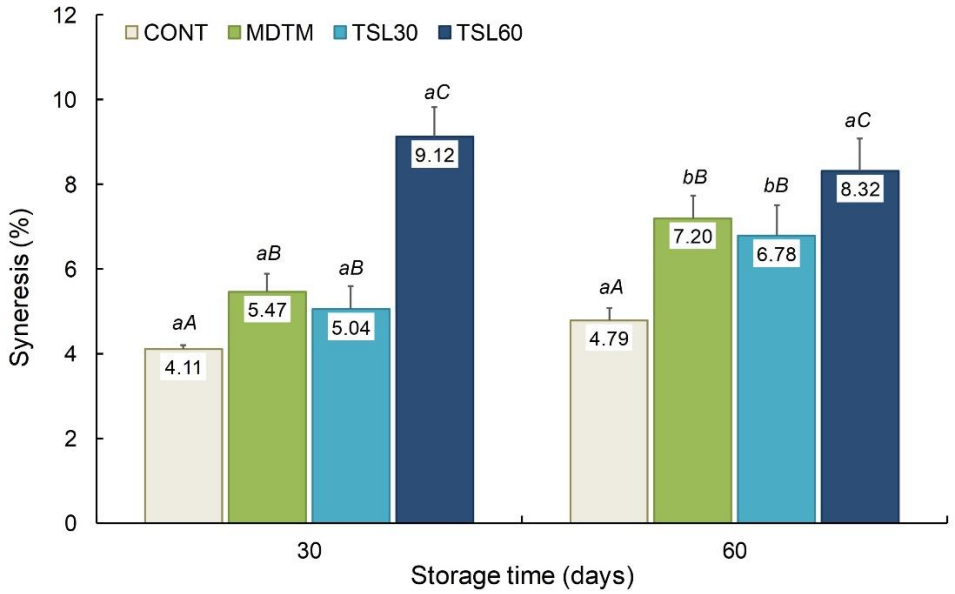

Fig. 1. Syneresis values of ready-to-eat broiler breast during cold storage (4 °C). CONT = control without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM = 30% of MDTM as substitution of broiler breast meat; and TSL30 and TSL60 = products containing 30 and 60% of TSL as substitution of broiler breast meat. Bars (+ standard error of mean) with a common uppercase letters (*A-C*), for the same day of storage, and lowercase letters (*a,b*), for the same treatment, did not differ (P>0.05).

Overall, the syneresis in the control sample did not differ ($P>0.05$) when stored for 30 or 60 days (mean of 4.45 ± 0.33%), but this behavior changed with the addition of MDTM or TSL. At low TSL additions (30%), there was an increase ($P<0.05$) in the syneresis of the products in relation to the control, but this did not differ ($P>0.05$) from the added MDTM samples in the same proportion. For these products (MDTM and TSL30) water losses increased from 5.26 ± 0.86% after 30 days of storage to 6.99 ± 1.10% after 60 days. However, higher TSL additions (60%) caused an increase ($P<0.05$) in syneresis values, which did not change between 30 and 60 days of storage (mean of 8.72 ± 1.26%). These differences can be explained by changes in moisture/protein ratio (M/P), which increased in products where the broiler breast (CONT, M/P = 3.82) was replaced by 30% MDTM or TSL (M/P = 4.37) and by 60% TSL (M/P = 4.99). Moreover, these differences are associated with reduced ability of MDTM and TSL proteins to immobilize water compared to the broiler breast meat, because a fair proportion of myofibrillar protein is damaged during the manufacture of MDPM (and therefore in the TSL), not being functional any longer (Pereira et al., 2011; Froning,1981).

The oxidative stability, estimated by the TBARS values, was different ($P<0.05$) between treatments, but was not affected ($P>0.05$) by the storage time (Table 5). The replacement of the broiler breast with 30% MDTM and 60% TSL increased ($P<0.05$) the TBARS values, while 30% TSL did not differ ($P>0.05$) with the control. Higher TBARS values for MDTM addition were expected due to the high lipid contents and to the fact that its phospholipid fraction of mechanically deboned poultry meat is highly unsaturated, and thus very susceptible to oxidation (Dawson and Gartner, 1983). Higher additions of TSL increase the TBARS values of the products, which was probably due to the presence of preformed aldehydes in the MDM which were not completely extracted by leaching procedure, or either due to the formation of these from primary products (hydroperoxides) of lipid oxidation. Moreover, oxidation of proteins is also believed to proceed via a free radical chain reaction like that of lipid oxidation, being both process correlated and influenced by each other (Ramos and Gomide, 2017). As many other macromolecules, muscle proteins are susceptible to oxidative reactions with myosin being the most sensitive (Lund et al., 2011; Soladoye et al., 2015) and, the protein oxidation in muscle food has often been associated with changes in solubility and protein functionality such as gelation and water holding capacity (Lund et al., 2011). This could help to explain the difference found between treatments for syneresis measurements describe early. However, despite the differences

in the TBARS values with the treatments, during the storage time the products did not oxidize. This is most probably due to the presence of nitrite in the formulation, since it has an excellent antioxidant effect (Dutra et al., 2017).

3.3 Texture profile and microstructure

The texture profile characteristics of the products are presented in Table 6. No differences were observed (*P>0.05*) in adhesiveness (0.22 ± 0.05 N×mm) in the products when broiler breast was replaced by MDTM or TLS. However, chewiness (125.09 ± 19.96 N×mm), cohesiveness (0.41 ± 0.04) and springiness (16.87 ± 0.41 mm) values were higher (*P<0.05*) in samples with MDTM or TSL than control. The hardness increased (*P<0.*05) when broiler breast was replaced with 30% MDTM or 30% TSL. Although the 60% TSL did not differ from these samples, it did not differ from the control either. These results did not confirm that control group had lower hardness and chewiness compared with that containing surimi-like material in low-fat pork patties (Choi et al. 2012); or, higher hardness and chewiness in sausages as reported by Wimmer et al. (1993).

Table 6. Texture profile attributes (means ± standard deviation) of ready-to-eat broiler breast.

Atributtes	**Formulations**				***Pr>F*[1]**
	CONT	**MDTM**	**TSL30**	**TSL60**	
Hardness (N)	13.44±1.42^{a}	18.78±1.30^{b}	18.91±0.94^{b}	16.05±1.97^{ab}	***0.005***
Cohesiveness	0.31±0.02^{a}	0.39±0.02^{b}	0.41±0.03^{b}	0.44±0.06^{b}	***0.012***
Adhesiveness (N×mm)	0.21±0.01	0.22±0.09	0.20±0.07	0.25±0.03	*0.502*
Springiness (mm)	15.36±0.14^{a}	16.96±0.63^{b}	16.58±0.38^{b}	17.06±0.22^{b}	***0.002***
Chewiness (N×mm)	63.89±9.50^{a}	125.09±11.49^{b}	128.72±10.04^{b}	121.47±29.34^{b}	***0.025***

CONT = control without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM = 30% of MDTM as substitution of broiler breast meat; and TSL30 and TSL60 = products containing 30 and 60% of TSL as substitution of broiler breast meat.

[1]Significant probabilities (*P<0.05*) were placed in bold.

[a-c]Means with different superscripts within a row are different (*P<0.05*).

According to Park (2014), the moisture content directly governs the overall quality and consistency of surimi. Variations in moisture during processing can unknowingly alter the

finished surimi properties, including gel strength (breaking force) and gel cohesiveness (deformation). Thus, this may be the important role of results obtained in the present study. As described before, the replacements of the broiler breast by MDTM or TSL increase the moisture/protein (M/P) ratio. In emulsified batters, the decrease in protein content and an increase in moisture content (as observed with MDTM addition) affects the mechanical properties of the products, reducing the cohesiveness, springiness and hardness by affecting the emulsification ability of the formulation (Crehan et al. 2000; Pereira et al, 2011). In restructured meat products, however, the water holding capacity becomes more important and the M/P ratio provided different behavior. Our results suggested that increasing M/P by MDTM or TSL additions increase hardness, chewiness, cohesiveness and springiness.

Regarding the hardness values, there was no difference observed between TSL60 and control and it seems to be due to a lower resistance caused by the presence of pores in the batter. In both the scanning electron microscopy (SEM, Fig. 2) and the light microscopy (Fig 3) images, it is possible to see large pores in the dense matrix structure of the TSL60 samples. This could be due to the carbon dioxide (CO_2) bubbles from the $NaHCO_3$ dissociation, which expands the meat batter during cooking conditions and form pores. Moreover, scattered pores with different size and depth described the remaining trapped water in the cooked meat batter (Ramadhan et al., 2014). Through the SEM images it is also possible to verify that the control matrix is less homogeneous and cohesive than the MDTM and TSL samples, which corresponds to the higher values of cohesiveness, springiness (flexibility) and even chewiness observed in these samples.

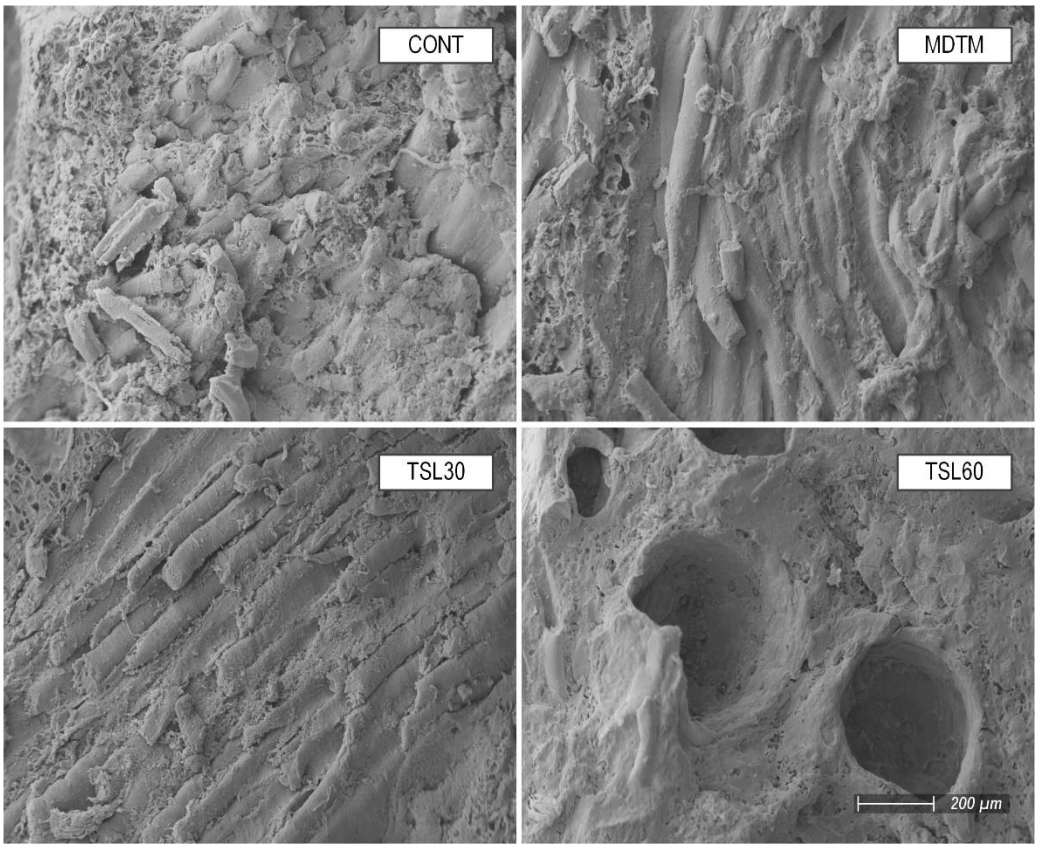

Fig. 2. Scanning electron microscopy (magnification of 180x) of the ready-to-eat broiler breast samples. CONT, products without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM, products with 30% MDTM; and TSL30 and TSL60, products with 30% and 60% TSL, respectively, as substitution of broiler breast meat TSL.

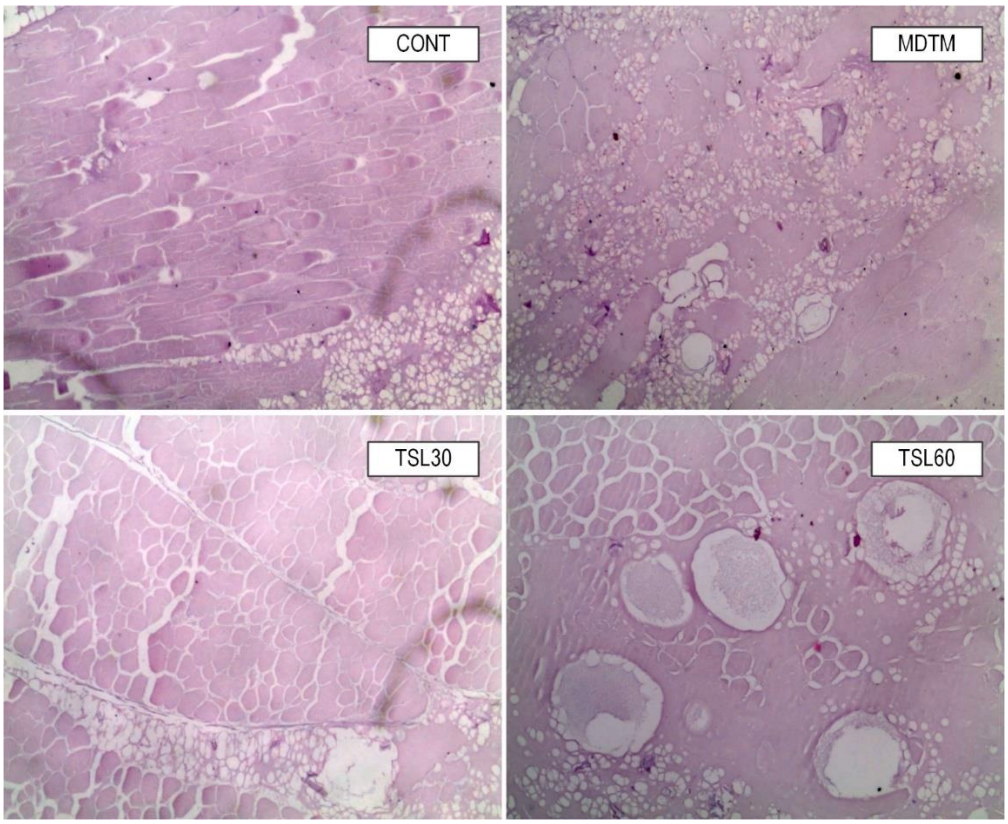

Fig. 3. Light microscope images (40X magnification) of the ready-to-eat broiler breast samples. CONT, products without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM, products with 30% MDTM; and TSL30 and TSL60, products with 30% and 60% TSL, respectively, as substitution of broiler breast meat TSL.

Still, in the light microscopy (Fig. 3) it is possible to distinguish great amount of adipocyte drops in samples added with MDTM than in the others, which could be due to the high fat content in this raw material.

3.4 Instrumental color

The results of the CIE color of ready-to-eat broiler breast as affected by the different treatments and storage time are presented in Table 7. Treatment x storage time interaction was not significant ($P>0.05$) for any response variables.

Table 7. Effects of treatment (T) and cold storage (S) on color characteristics (means ± standard deviation) of ready-to-eat broiler breast.

Effect	**Source of variation**	**Lightness (*L**)**	**Redness (*a**)**	**Yellowness (*b**)**	**Chroma (*C**)**	**Hue angle (*h, graus*)**
Treatment (T)	CONT	77.76 ± 0.91[a]	3.59 ± 0.26[a]	13.95 ± 1.19	14.41 ± 1.12	75.44 ± 1.92[a]
	MDTM	70.64 ± 1.53[b]	5.85 ± 0.77[b]	14.79 ± 0.44	15.92 ± 0.55	68.46 ± 2.51[b]
	TSL30	73.67 ± 1.32[b]	2.75 ± 0.17[ac]	14.39 ± 1.01	14.65 ± 1.01	79.18 ± 0.61[c]
	TSL60	71.31 ± 2.84[b]	2.47 ± 0.52[c]	15.02 ± 1.33	15.23 ± 1.34	80.66 ± 1.91[c]
Storage periods, days (D)	0	73.05 ± 3.12	3.56 ± 1.51	13.87 ± 0.99[a]	14.38 ± 1.18[a]	75.81 ± 5.33
	30	73.40 ± 3.65	3.74 ± 1.41	14.61 ± 0.89[b]	15.14 ± 0.93[b]	75.66 ± 5.16
	60	73.58 ± 3.40	3.69 ± 1.48	15.14 ± 1.04[c]	15.64 ± 1.07[b]	76.34 ± 5.26
Pr>F[1]	T	***0.001***	***<0.001***	*0.540*	*0.253*	***<0.001***
	D	*0.733*	*0.592*	***<0.001***	***<0.001***	*0.564*
	T x D	*0.781*	*0.793*	*0.461*	*0.430*	*0.793*

CONT = control without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM = 30% of MDTM as substitution of broiler breast meat; and TSL30 and TSL60 = products containing 30 and 60% of TSL as substitution of broiler breast meat.

[1]Significant probabilities (*P<0.05*) were placed in bold.

[a-c]Means with different superscripts within a column are different (*P<0.05*).

The treatments affected ($P<0.05$) lightness (L^*), redness (a^*) and hue angle (h), whereas yellowness (b^*) and chroma (C^*) vary due to storage time. The chromacity coordinates were differently affected by the treatments: the a^* values were significantly affected by the treatments ($P<0.05$), while b* values alter ($P<0.05$) due to the storage time. Thus, in the present study, the values of a^* were correlated with the changes h values, whereas the differences in C^* values are attributed to b^* values. The yellowness (b^*) increased ($P<0.05$) during the storage time.

The replacement of breast meat by MDTM or TSL made the products darker (lower L^* values), regardless the amount of raw material used. Samples with MDTM added becoming redder (lower h values) and with TSL becoming yellower (higher h values) than control ones. A darker and redder tone in products with MDTM was expected due to the higher heme pigment content in this raw material (Massingue, 2018a; Pereira et al., 2011), especially hemoglobin released from bone marrow (Contreras-Castillo et al. 2008). Hernandez et al. (1986) also reported that cooked patties containing unwashed MDTM was darker in color than samples manufactured with broiler breast. However, it was expected an increasing on lightness to the surimi-like based products (Choi et al. 2012). A decrease of L^* values of the products containing TSL could be explained by the lower light scattering on the sample. Light entering meat product is scattered by its complex microstructure and depends of the refractive index of its components (Ramos and Gomide, 2017). Therefore, the addition of MDTM or TSL could allowed the formation of a more homogeneous protein matrix (as observed in Fig 2), reducing the differences in the refractive index between its components. This make the incident light penetrates deeply into the products, which then appears dark and strongly pigmented. In the case of TSL, due to its less heme pigment content (Massingue, 2018), samples made with addition of this raw material were yellowish. Fig. 4 illustrate the color differences of the ready-to-eat breast broiled products elaborated.

Desmond and Kenny (1998) also observed that lightness of frankfurters decreased as the level of beef heart surimi-like was increased. However, Wimmer et al. (1993) and Murphy et al. (2004) did not observe any difference in L^* values of frankfurters manufactured with pork and fish surimi-like material, respectively.

Regardless of the color tone of the treatment sample, the color intensity (chroma, C^*) slight increased ($P<0.05$) between 1 to 30 days, while it remained constant up to 60 days of storage, and its change during storage seems to be due to syneresis of the products.

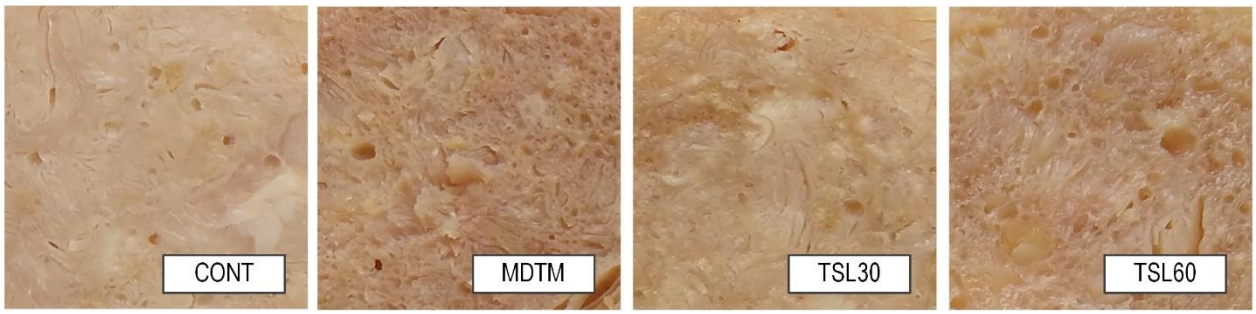

Fig. 4 Pictures of the ready-to-eat broiler breast products: Control, elaborated without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM, elaborated with 30% MDTM as substitution of broiler breast meat; and TSL30 and TSL60, elaborated with 30 and 60% of TSL, respectively, as substitution of broiler breast meat.

3.5 Microbiological analysis

Clostridium sulphite reductant and *Coliforms thermotolerants* at 45°C were not detected in samples evaluated during the storage time (1, 30 and 60 days). Other bacterial counts throughout the storage are shown in Table 8, being not affected ($P>0.05$) by treatment or by its interaction with storage time. However, the storage period affected ($P<0.05$) individually the whole groups of microorganisms evaluated and ranged from 5.30 to 6.68 log CFU/g.

Latic acid bacteria (LAB) and psychrotrophic bacteria growth in the first 30-days of storage, remained constant up to 60-d, while mesophilic bacteria growth during all storage period. Recontamination can occur after cooking under the chilling process what apparently results from exposure to an airborne microorganism. Manipulation and equipment are among the most likely sources of contamination during packaging and slicing (Korkeala and Bjorkroth, 1997). Thus, the shelf life of sliced cooked ham sausage type meats packed in a modified atmosphere or vacuum is extremely limited to few (between three or two) weeks of storage (Dušková et al., 2016). Generally, an increase of spoilage bacteria, including mesophilic and psychrotrophic counts, under the storage time in meat and meat products were reported by various studies (Murphy et al., 2004; Mataragas et al., 2007; Pothakos, Samapundo & Devlieghere, 2012).

The slight decrease observed in pH values (from 6.48 to 5.85) during storage (Table 5) can be associated with the LAB development during this period. LAB multiplication has been

reported as the main cause of cured and cooked meat product spoilage (Mataragas et al., 2007), but the values observed in this experiment after 60-days at 4°C were lower than those (8.72±0.16 log CFU/g) reported by Dušková, Kameník, Lačanin, Šedo, & Zdráhal (2016) in sliced cooked ham stored for 8 weeks at 2°C.

Table 8. Effects of treatment (T) and cold storage (S) on microbiological quality (means ± standard deviation) of ready-to-eat broiler breast.

Effect	Source of variation	Acid lactic bacteria (log CFU/g)	Mesophilic bacteria (log CFU/g)	Psychrotrophic (log CFU/g)
Treatment (T)	CONT	3.68 ± 2.32	4.42 ± 2.65	4.76 ± 2.94
	MDTM	3.43 ± 2.46	4.52 ± 2.76	4.44 ± 2.76
	TSL30	4.19 ± 2.48	3.95 ± 2.51	3.78 ± 2.61
	TSL60	4.26 ± 2.93	4.78 ± 3.01	4.45 ± 2.80
Storage periods, days (D)	0	nd	nd	nd
	30	5.30 ± 1.55[a]	5.56 ± 0.83[a]	5.93 ± 0.38[a]
	60	5.88 ± 1.28[a]	6.68 ± 0.59[b]	6.48 ± 1.16[b]
Pr>F[1]	T	*0.547*	*0.0983*	*0.350*
	D	***<0.001***	***<0.001***	***<0.001***
	T x D	*0.134*	*0.149*	*0.186*

nd = not detected. CONT = control without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM = 30% of MDTM as substitution of broiler breast meat; and TSL30 and TSL60 = products containing 30 and 60% of TSL as substitution of broiler breast meat.

[1]Significant probabilities ($P<0.05$) were placed in bold.

[a-c]Means with different superscripts within a column are significantly different ($P<0.05$).

3.6 Sensory evaluation

Most of the 55 panelists (98.18%) were between 18 and 30 years old (1.82% was between 45 and 60 years old) and were females (74.55%). Moreover, 63.64% of the judges reported that they consumed cured and cooked meat type products once per week, 18.18% twice a week, 7.27% twice a month, 3.64% approximately once per month, 1.82% almost every day and 5.45% related that they rarely have consumed this type of products.

3.6.1 Acceptance test

The results of the appearance, flavor, texture, and overall impression of all ready-to-eat products are shown in Table 9. The treatments affected (*P<0.05*) all sensorial attributes. Overall, except for appearance, the replacement of broiler breast meat by MDTM or TSL material reduced the acceptability of the products. MDTM or 30% TSL addition reduced (*P<0.05*) the sensory scores for flavor, texture and overall impression, but did not differ (*P>0.05*) to the appearance of control samples. In contrast, when the greater amount of TSL (60%) was used in the product formulation, all sensory acceptance were reduced (*P<0.05*) in relation to the other treatments, with the exception of the appearance which did not differ (*P>0.05*) to TSL30. The panelists related TSL60 treatment with scores of "disliked slightly" for its appearance and texture and as "neither liked either disliked" to flavor and overall impression.

Table 9. Scores (mean ± standard deviation) from consumer sensory panel assessments for ham sausages using a 9-point hedonic scale[1].

Attributes	**CONT**	**MDTM**	**TSL30**	**TSL60**	**Pr>F[2]**
Appearance	5.82 ± 2.10^{ab}	6.22 ± 1.81^{a}	5.24 ± 1.93^{bc}	4.64 ± 1.88^{c}	***<0.001***
Flavor	7.76 ± 0.98^{a}	6.35 ± 1.79^{b}	6.62 ± 1.34^{b}	5.51 ± 2.02^{c}	***<0.001***
Texture	7.62 ± 1.05^{a}	6.89 ± 1.61^{b}	6.67 ± 1.50^{b}	4.98 ± 1.97^{c}	***<0.001***
Overall Impression	7.55 ± 1.05^{a}	6.44 ± 1.74^{b}	6.38 ± 1.35^{b}	5.18 ± 1.93^{c}	***<0.001***

CONT = control without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM = 30% of MDTM as substitution of broiler breast meat; and TSL30 and TSL60 = products containing 30 and 60% of TSL as substitution of broiler breast meat.

[1] Score 1 = "disliked extremely"; 5 = "neither liked/disliked"; and 9 = "liked extremely".

[2] Significant probabilities (*P<0.05*) were placed in bold.

[a-c]Means with different superscripts within a row are different (*P<0.05*).

On the other hand, by an internal preference map (IPM) (Fig. 5), the samples could be separated in three groups distinct, in which TSL30 and TSL60 treatments were group together for appearance, and control and TSL30 grouped for flavor, texture and overall impression attributes.

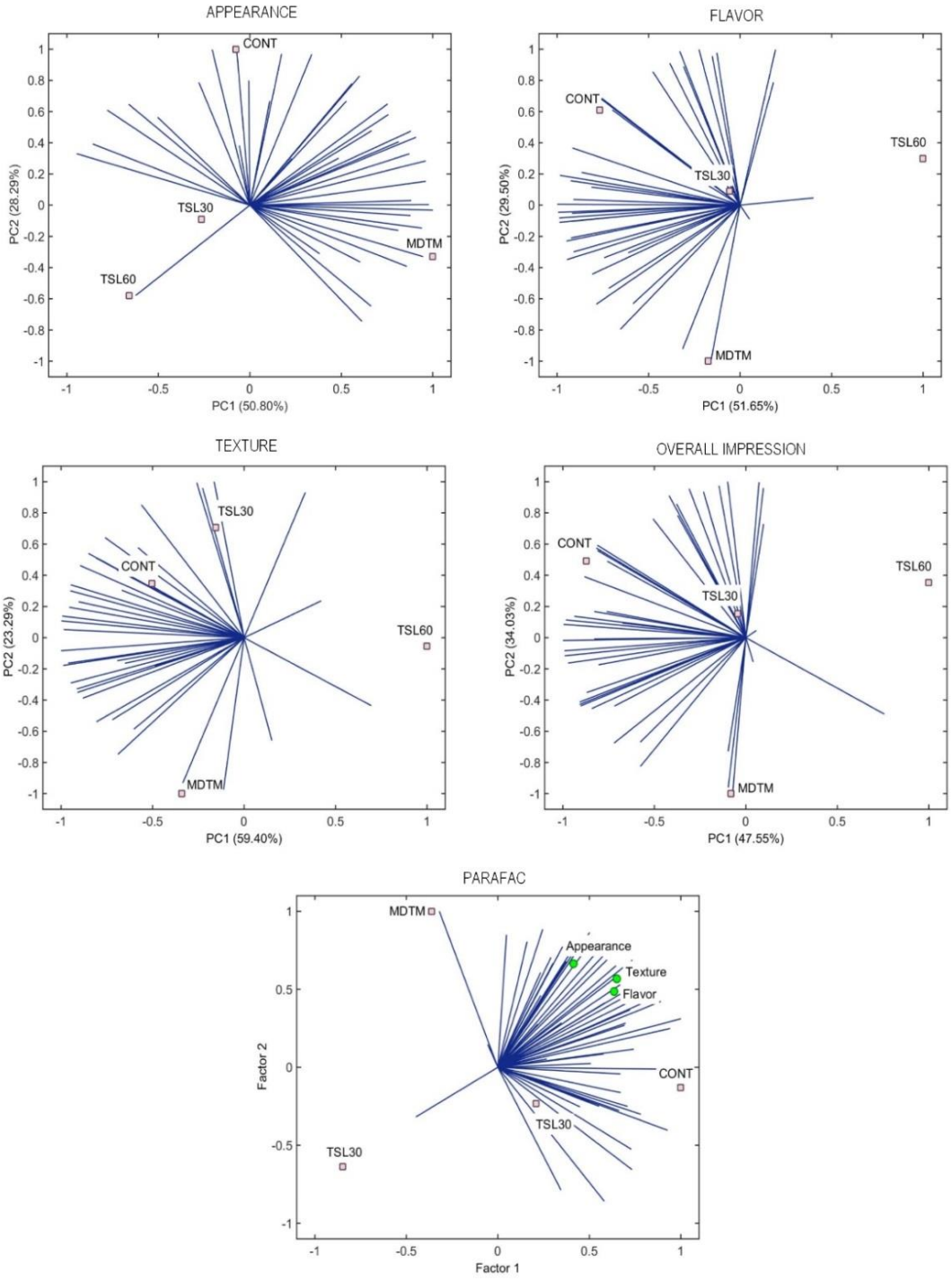

Fig. 5. Internal preference maps (IPM) for the appearance, flavor, texture and overall impression attributes and the Tri-plot (PARAFAC) map of the ready-to-at broiler breast samples. CONT = control without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM = 30% of MDTM as substitution of broiler breast meat; and TSL30 and TSL60 = products containing 30 and 60% of TSL as substitution of broiler breast meat.

A tri-plot of appearance, flavor, and texture was also generated resulting in the PARAFAC plot, wherein the correlations between the samples, consumers, and sensory attributes are shown simultaneously. For all parameters, the first two principal components of the IPM explained approximately 80% of the variance in the data. Moreover, the Core Consistency Diagnostic (CORCONDIA) of the PARAFAC model explained 64.91% of the correlation and 57.56% of the variance between these two factors. Nunes et al. (2011) reported that at least 45% of the variance in the data and a 64% of CORCONDIA indicated that the model was adequate.

The spatial separation resulted from PARAFAC also forming three distinct groups of samples. The two principal components (PC1 and PC2) clearly showed that samples CONT and TSL30 were the most preferred by consumers for all attributes, followed by samples MDTM and with TSL60 out of the consumer's range score in all attributes evaluated. This behavior for the products containing a high amount (60%) of TSL could compromise their sensory acceptance in the present study.

Similar results were observed by Hernandez et al. (1986), who showed that the addition of washed mechanically deboned turkey meat amounts up to 50% in turkey breast patties was related undesirable by a sensory panel. Previous work from Ismail et al. (2014) did not find a significant effect on the mean sensory scores due to the use of duck surimi-like in duck sausages. Moreover, Wimmer et al. (1993) suggested limited applications of the surimi-like obtained from mechanically deboned pork since it has observed little improvement with its use in the texture or water binding in frankfurters over those with unwashed ones. However, in this study, using 30% of TSL seems to be promising, since it has lower effects on the acceptance sensory scores.

3.6.2 CATA questions

An external preference map (EPM) was generated from the number of times that the consumers associated each of the 18 terms of the CATA questions (Table 2) with the samples and overall impression scores from the acceptance test. Only the slopes for 22 consumers (from the 55 participants) provided valid models ($P \leq 0.30$), which were plotted on the map upon two principal components (Fig. 6). The two principal components plots show the relative positions of the samples score plots and factor loadings indicate the attributes that best describe the dimensions of the perceptive space. Combined, the two principal components accounted for

83.30% of the total variance in the data after fitting by the vector model with a coefficient of determination (R^2) of 0.966. This probability showed how the consumers agreed with the product characteristics.

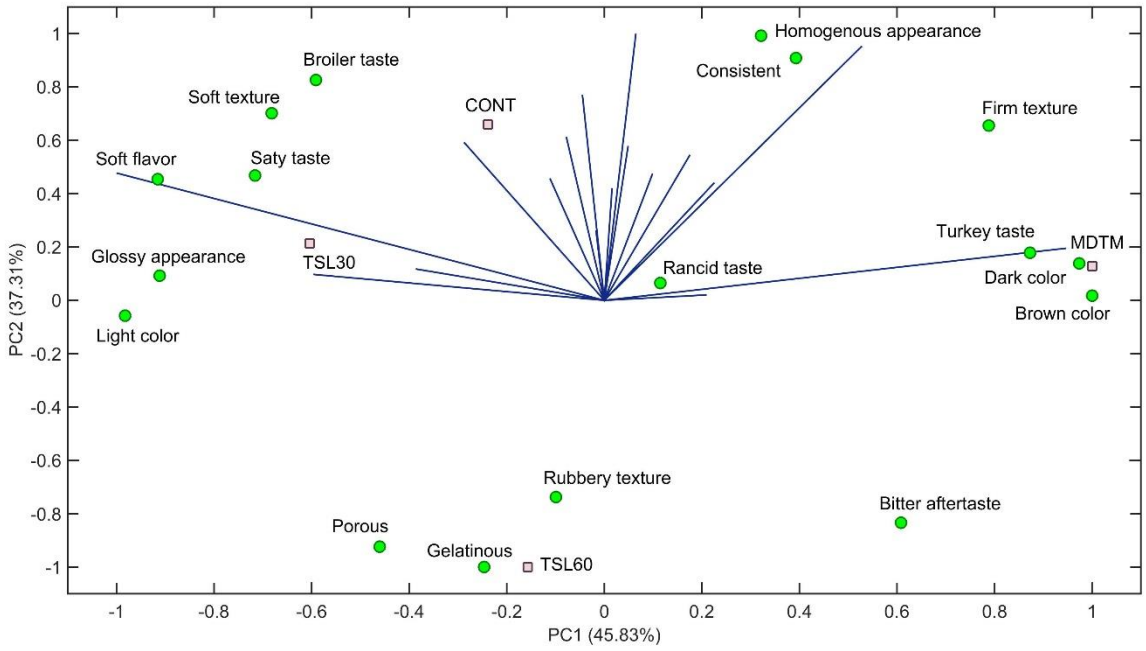

Fig. 6. External preference map (EPM) of the sensory terms on the check-all-that-apply (CATA) questionnaire for ready-to-eat broiler breast samples in the correlation matrix with overall consumer impression. CONT = control without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM = 30% of MDTM as substitution of broiler breast meat; and TSL30 and TSL60 = products containing 30 and 60% of TSL as substitution of broiler breast meat.

The most frequently used terms marked by participants were as follows: “light color”, “porous”, “broiler taste”, “turkey taste”, “soft flavor”, “soft texture”, and “consistent”. Such terms may be considered the most appropriate in the description of the samples by consumers. The least used terms were as follows: “Brown color”, “dark color”, “homogenous”, “glossy appearance”, “rancid taste”, “salty taste”, “bitter aftertaste”, “firm”, “rubbery texture” and “gelatinous”.

The results of CATA analysis clearly indicate that CONT and TSL30 were related with “broiler taste”, “soft texture”, “soft flavor”, “salty taste”, “glossy appearance” and “light color”. Moreover, the MDTM was perceived with “homogenous appearance”, “dark color” and “brown color”, “consistent”, “firm texture”, “turkey taste”, and “rancid taste”. The “porous”, “rubbery texture” and “gelatinous” characteristics were related to TSL60.

From this analysis, it is observed that the use of low amount (30%) of TSL allow getting the most for the replacement of broiler breast meat, since it maintains the light color and soft taste, which is expected in poultry products without masking the taste of broiler by the taste of the origin of the surimi-like material (in the case, turkey). On the other hand, MDTM confers adverse characteristics, although it is possible to observe a preference of consumers evaluated by products for the appearance provided by this raw material (Fig. 5), which provide the darker and brownish color. Further, this preference is due to the fact that the Brazilian consumer is used to eat meat products that have darker appearance from mechanically deboned meat, as demonstrated by Pereira et al. (2016), since its use is allowed in several meat products in Brazil. For the CATA, it was also possible to verify the reasons for the high rejection of the TSL60 samples, especially for the description of porous appearance and rubbery texture, characteristics clearly observed by the texture profile analysis and the micrographs images (Fig. 2 and 3).

Moreover, the related terms of the “bitter aftertaste” flavor to TSL60 and MDTM together may be concerning the perceptive flavor of rancid progress found in the TBARS analysis. According to AMSA (2012), TBARS values correlate well with sensory tasting. Unluckily, there are few studies concerning sensory profile of meat products with the addition of surimi-like material (neither involving CATA analysis) that could provide a better base for comparison with present results.

3.63 Instrumental and sensorial relationship

The biplot for the first two principal components (PCA) given in Fig. 7, correlates the panel loadings of CATA questions for visual color and perceptive texture of the samples and their instrumental color and texture.

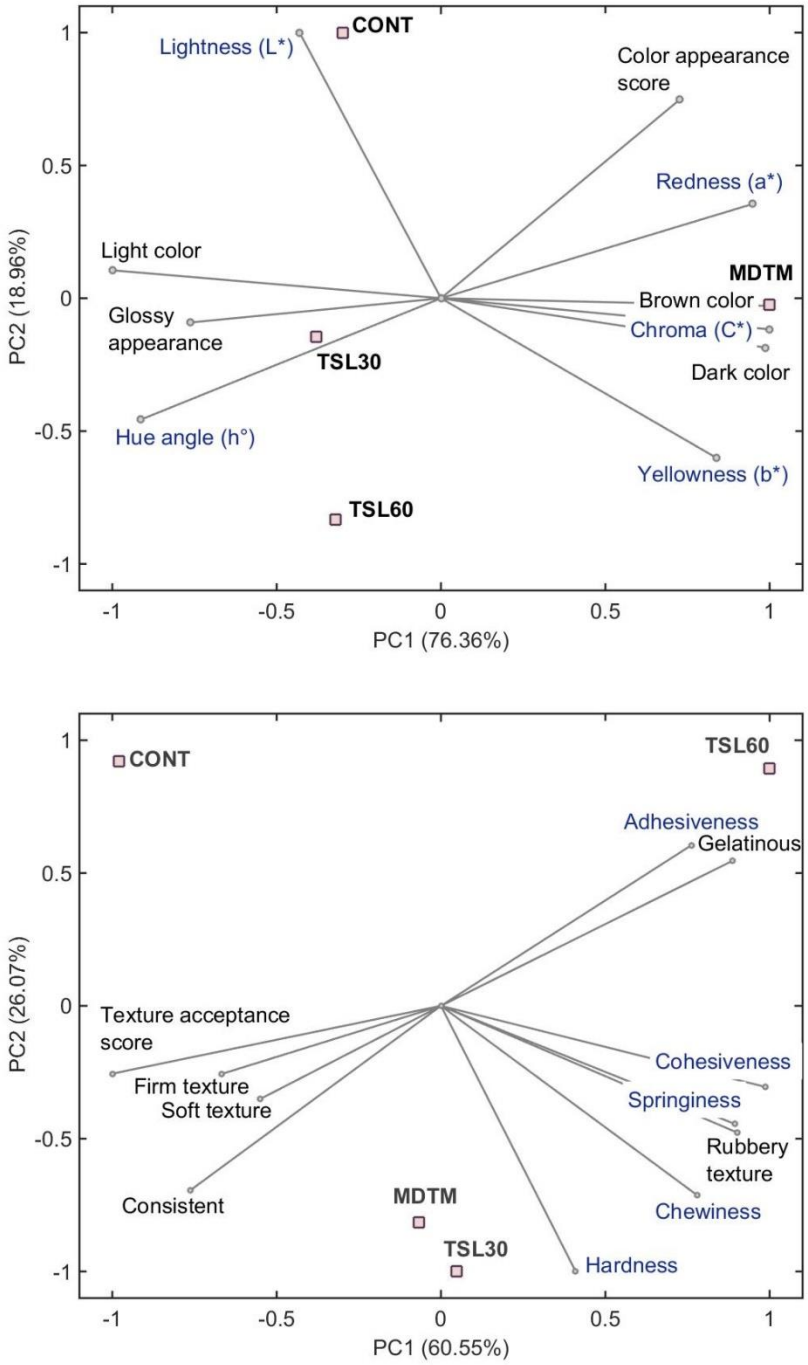

Fig. 7. Principal component analysis (PCA) of color and texture instrumental analysis and sensory scores from the CATA terms of the ready-to-eat broiler breast samples. CONT = control without turkey surimi-like (TSL) and mechanically deboned turkey meat (MDTM); MDTM = 30% of MDTM as substitution of broiler breast meat; and TSL30 and TSL60 = products containing 30 and 60% of TSL as substitution of broiler breast meat.

Samples lying together have similar properties and variables close together are positively correlated. Variables to different axes have a low correlation and variables lying opposite to each other in the loading plot tend to have a negative correlation (Jorge et al., 2015).

For color and appearance characteristics, the PCA explained 95.32% of the total variance, most of by the first component (76.36%). As observed for appearance IPM, two groups were formed and separated clearly: 1) CONT; TSL30 and TSL60, and 2) MDTM. The brown and dark color perceptions were highly related to the saturation (C^*) of the samples, being this appearance also correlated with the preference (sensory scores) of the consumer. Thus, lighter samples (higher L^* values) and more yellowish (higher h values) were less preferred, even in the case of a poultry meat product.

For texture characteristics, the PCA explained 86.62% of the total variance, most of by the first component (60.55%). As observed for texture IPM, three groups were also formed: 1) CONT; 2) MDTM and TSL30; and 3) TSL60. Unlike the color analysis, the texture attributes by the TPA test could not be correlated to a sensory perception only, except for the adhesiveness that was related to the gelatinous.

All other attributes of the TPA test were related to rugged texture perception. However, consumers preferred (sensory score) products with firm and soft texture and consistent texture, despite these attributes were not related to the hardness and / or chewiness of the TPA test as might be expected.

Satisfactory linking between the PCA analysis and the responses of the CATA questionnaire was found in this study, despite the lowest cases that it was not enough to give closely relative features. About that finding, Válková et al. (2007) reported that even the PCA analysis had shown better results in samples from pork cooked ham, only the total results from instrumental, chemical and sensory analyses were needed to explain the total variance.

4 Conclusions

The use of turkey surimi-like (TSL) material instead a mechanically deboned turkey meat as substitute of broiler breast meat improved physicochemical and sensory properties of a low-fat ready-to-eat poultry product. However, samples with the addition of 60% TSL had the highest values of syneresis during the storage time, with high oxidative index and poor texture, due to a

numerous porous in its microstructure, presenting lower acceptance scores than other treatments. It concluded that 30% TSL could be applied in ready-to-eat broiler breast, maintaining the low-fat content and conferred good color and texture properties, without mask the broiler taste or change the psychochemical characteristics of the products.

Acknowledgements

The author would like to thank the Brazilian funding agencies: Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq; 430206/2016-0) and the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG; CVZ APQ-02015-15 and CVZ APQ-02904-17) for their financial support. The author also grateful to the Government of Mozambique and to the Brazilian agency Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the scholarship granting (Doctorate Degree) by the Programa de Estudantes-Convênio de Pós-Graduação (PEC-PG/CAPES).

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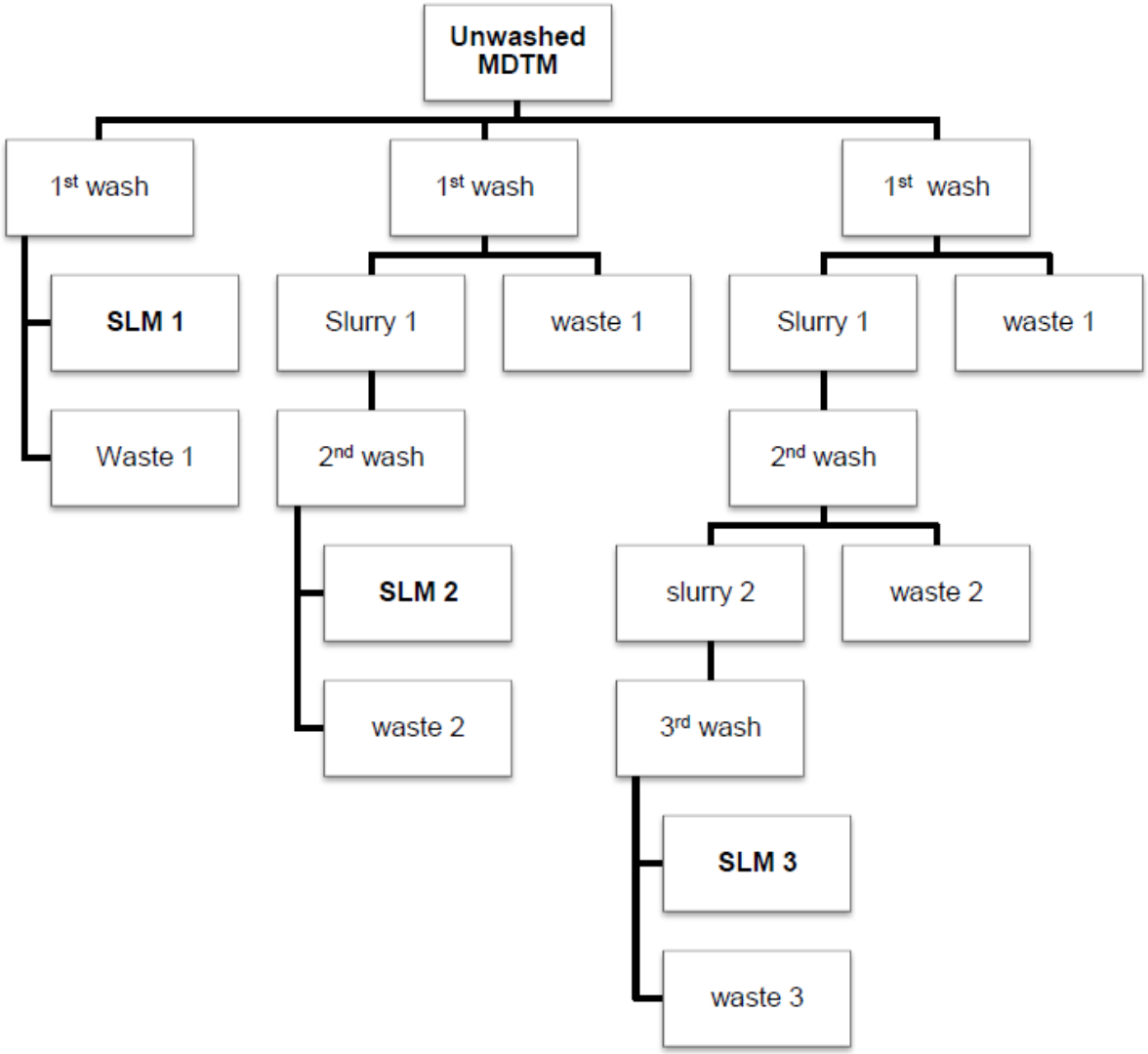
APPENDICES

APPENDIX A – Flow chart of surimi-like material processing



APPENDIX B – Summary of the analysis of variance (ANOVA) of pH and protein content of the waste solutions from washed mechanically deboned turkey meat

Source	DF	Mean Square[1]	
		pH	Protein content
Intercept	1	**3849.529**	**382.9652**
WS	3	**9.169**	**2.7568**
WC	2	**1.614**	**132.3453**
WS*WC	6	**0.188**	**1.7538**
Error	84	0.021	0.2263
Total	95		

APPENDIX C – Summary of the analysis of variance (ANOVA) of proximate composition of surimi-like material made from mechanically deboned turkey meat

Source	DF	Mean Square[1]			
		Moisture	Fat	Protein	Ash
Intercept	1	**274636.294**	**1966.552**	**9433.378**	**49.930**
WS	3	**44.922**	3.970	**20.813**	**0.471**
WC	2	**82.428**	**32.603**	**13.437**	0.013
WS*WC	6	3.742	3.288	1.619	0.021
Error	35	1.713	1.412	1.209	0.016
Total	46				

Appendix D – Summary of the analysis of variance (ANOVA) of collagen and minerals sodium and calcium contents in surimi-like material made from mechanically deboned turkey meat

Source	DF	Mean Square[1]		
		Collagen (mg/g)	Sodium (mg/100g)	Calcium (%, DMB)
Intercept	1	**36.99289**	**462413.710**	**580.552**
WS	3	0.11821	**135929.772**	2.127
WC	2	**0.34618**	1271.000	1.686
WS*WC	6	0.05108	3043.685	1.128
Error	24	0.08645	5664.580	1.541
Total	35			

APPENDIX E – Summary of the analysis of variance (ANOVA) of physicochemical composition of the surimi-like material made from mechanically deboned turkey meat

Source	DF	Mean Square[1]					
		pH	**Yield (%)**	**SSP (mg/g)**	**MSP (mg/g)**	**WHC**	**Aw**
Intercept	1	**2333.417**	**56306.483**	**13291.189**	**284630.409**	**4.480**	**46.229744**
WS	3	**4.317**	**85.996**	**398.630**	**479.884**	**0.059**	0.000034
WC	2	**0.336**	**120.220**	**150.220**	263.758	0.001	0.000062
WS*WC	6	**0.132**	13.392	15.228	47.448	**0.008**	0.000025
Error	36	0.029	7.446	39.285	160.616	0.003	0.000038
Total	47						

APPENDIX F – Summary of the analysis of variance (ANOVA) of the heme pigments, metmyoglobin and instrumental color of surimi-like material made from mechanically deboned turkey meat

Source	DF	Mean Square[1]							
		Heme Pigments (mg/g)	**MMb2[a] (%)**	***L****	***a****	***b****	***C****	***h****	**Whiteness**
Intercept	1	**309.077**	**59881.357**	**182872.157**	**12317.469**	**16255.261**	**29217.083**	**118157.186**	**140945.688**
WS	3	**27.921**	**196.542**	**225.72**	**357.183**	**5.87**	**202.176**	**876.957**	**416.199**
WC	2	**7.903**	13.795	**21.078**	**90.39**	**19.349**	**79.861**	**161.94**	**74.667**
WS*WC	6	0.502	6.037	3.931	**7.775**	2.243	**4.873**	**41.151**	6.477
Error	35	0.418	6.58	5.177	1.813	1.681	1.968	7.206	3.977
Total	46								

[a]) Error: DF=36, Total: DF=47.

APPENDIX G – Summary of analysis of variance (ANOVA) of the cooking loss and instrumental texture profile analysis of cooked gels made from turkey surimi-like material

Source	DF	Mean Square[1]					
		Cooking loss	Hardness	Cohesiveness	Adhesiveness	Springiness	Chewiness
WS	3	**665.440**	**1872.160**	**0.009**	**0.227**	2.628	**213308.700**
WC	2	**29.668**	**425.040**	**0.004**	**0.053**	1.724	**55995.300**
SL	1	**1621.557**	**3941.650**	**0.008**	**0.003**	**117.281**	**704940.200**
WS*WC	6	12.424	**403.420**	0.003	**0.050**	1.442	**94506.820**
WS*SL	3	**39.036**	56.790	**0.008**	**0.035**	3.431	27012.090
WC*SL	2	**42.305**	2.190	0.000	**0.124**	3.541	**408.511**
WS*WC*SL	6	1.874	**59.370**	0.001	**0.124**	1.671	**29820.200**
Error	52	9.659	23.270	0.001	0.008	2.261	3960.977
Total	77						

APPENDIX H – Summary of the analysis of variance (ANOVA) of the proximate composition of ready-to-eat restructured meat product

Source	DF	Mean Square[1]			
		Moisture	Fat	Protein	Ash
Intercept	1	**56940.23**	**37.01397**	**3011.314**	**95.67761**
Sample	3	**13.31**	**2.64597**	**8.413**	**0.44149**
Error	6	1.13	0.07049	0.446	0.03871
Total	9				

APPENDIX I – Summary of the analysis of variance (ANOVA) of the physicochemical characteristics of the ready-to-eat restructured meat product

Source	DF	Mean Square[1]			
		pH	**Syneresis**	**aw**	**TBARS**
Intercept	1	**1360.770**	**645.9136**	**34.12702**	**7.415975**
Sample	3	**0.347**	**12.5628**	**0.00003**	**0.432754**
Time	2	**1.227**	**163.5747**	**0.00003**	0.025418
Sample*Time	6	0.011	**4.2259**	0.00000	0.006227
Error	24	0.025	0.6193	0.00000	0.028075
Total	35				

APPENDIX J – Summary of the analysis of variance (ANOVA) of instrumental color of ready-to-eat restructured meat product

Source	DF	Mean Square[1]					
		L*	***a****	***b****	***C****	***h** (graus)*	**Whiteness**
Intercept	1	**193666.0**	**483.0471**	**7609.654**	**8157.965**	**207600.9**	**173138.8**
Sample	3	**93.1**	**21.1535**	1.977	**4.030**	**267.0**	**84.8**
Time	2	0.9	0.1083	**4.837**	**4.836**	1.5	0.1
Sample*Time	6	1.4	0.1099	0.245	0.281	1.3	0.8
Error	24	3.9	0.2821	1.014	0.991	4.2	3.6
Total	35						

APPENDIX K – Summary of the analysis of variance (ANOVA) of instrumental texture profile of ready-to-eat restructured meat product

Source	DF	Mean Square[1]				
		Hardness	**Cohesiveness**	**Adhesiveness**	**Springness**	**Chewiness**
Intercept	1	**2358.446**	**1.371536**	**0.529542**	**3303.844**	**120809.6**
Sample	3	**19.095**	**0.008637**	0.002593	**2.792**	**3071.0**
Error	6	2.489	0.001347	0.003199	0.048	434.2
Total	9					