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PROGRAMA DE PÓS-GRADUAÇÃO EM BIOTECNOLOGIA MARINHA

BRUNO DE CARVALHO BONFIM

SUBSTITUIÇÃO PARCIAL DA FARINHA DE TRIGO POR FARINHA DO PEIXE (*Priacanthus arenatus* - Cuvier, 1829), EM *NUGGETS*: MELHORA NUTRICIONAL E PERSPECTIVA DO CONSUMIDOR

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Trabalho de dissertação de mestrado, apresentado ao Instituto de Estudos do Mar Almirante Paulo Moreira e à Universidade Federal Fluminense, como requisito para a obtenção do grau de Mestre em Biotecnologia Marinha.

Orientadora: Profa. Dra. Alejandra Filippo Gonzalez Neves dos Santos

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Substituição parcial da farinha de trigo por farinha do peixe (*Priacanthus arenatus* - Cuvier, 1829*)*, em *nuggets*: melhora nutricional e perspectiva do consumidor

Dissertação apresentada ao Instituto de Estudos do Mar Almirante Paulo Moreira e à Universidade Federal Fluminense, como requisito para a obtenção do título de Mestre em Biotecnologia Marinha.

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Arraial do Cabo, 25 de Junho de 2018

Dedico este trabalho á minha família, amigos e a todos que diretamente e indiretamente contribuíram para a minha trajetória. Sem o apoio e amor incondicional deles não seria possível realizar esse sonho.

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“E se o mundo não corresponde em todos os aspectos a nossos desejos, é culpa da ciência ou dos que querem impor seus desejos ao mundo?”

Carl Sagan

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Biografia

Licenciado em Ciências Biológicas pela Universidade Estadual do Norte Fluminense Darcy Ribeiro, UENF. Tem experiência na área de docência onde atuou como bolsista no programa PIBID - Programa de Iniciação à Docência, na preparação e aplicação de aulas práticas no CIEP 057 Nilo Peçanha, Campos dos Goytacazes - RJ. Atuou como estagiário em projeto de estatística pesqueira junto ao órgão FIPERJ- Fundação e Instituto de Pesca do Estado do Rio de Janeiro, desenvolvido em Atafona, São João da Barra - RJ. Atuou como bolsista de apoio em projeto de ecologia marinha desenvolvido no LCA- Laboratório de Ciências Ambientais da UENF. Desenvolveu a pesquisa de monografia tendo como objeto de estudo a "Caracterização da atividade pesqueira extrativa Marinha em Atafona, São João da Barra- RJ".

Desenvolveu a presente pesquisa de Mestrado, realizando subproduto de pescado com orientação da Profa. Dra. Alejandra Filippo G. N. dos Santos - Laboratório de Ecologia Aplicada, Departamento de Zootecnia e Desenvolvimento Agrossocioambiental Sustentável (UFF) e co-orientação de Prof. Dr. Carlos Adam Conte-Junior - Departamento de Tecnologia de Alimentos – UFF, da Faculdade de Veterinária.

Teve participação no projeto de extensão "Biossegurança na Pesca de Jurujuba", UFF e atualmente atua no projeto de educação ambiental junto às comunidades pesqueiras de Arraial do Cabo pelo PESCARTE, desenvolvido e aplicado pela UENF.

RESUMO

Embora o beneficiamento de pescado seja uma alternativa ao aumento do consumo de peixe, cerca de 30 a 40% da matriz é utilizado no processo, sendo o restante descartado como resíduos como cabeça, carcaça e vísceras. A utilização de resíduos de peixe é uma alternativa para um melhor aproveitamento da matéria-prima, agregando valor, elaborando novos produtos alimentícios nutritivos, aumentando a rentabilidade, reduzindo os custos de insumos e reduzindo a quantidade de resíduos descartados no final. O presente trabalho visa utilizar parte dos resíduos descartados no processamento de pescado para a fabricação de farinha de peixe e utilizá-lo na substituição parcial da farinha de trigo de um produto reestruturado tipo *nuggets* para aumentar seu valor nutritivo. Aproximadamente dez kg de filé de peixe foram usados para fazer as *nuggets* e dois kg de polpa de peixe foram usados para fazer farinha de peixe. A farinha de trigo (FT) usada para bater nas *nuggets* foi parcialmente substituída por farinha de peixe (FP). Quatro formulações foram testadas: controle T1 (100% FT), T1 (90% FT/10% FP), T2 (75% FT/25% FP) e T3 (60% FT/40% FP). Proteína, lipídios, cinzas, umidade, carboidratos e valor energético foram analisados para determinar a composição química dos produtos. Análises instrumentais de cor e texturas foram realizadas para verificar as características físicas dos *nuggets* e análise sensorial para verificar a aceitação do produto e as principais características percebidas pelos consumidores. Os *nuggets* com farinha de peixe apresentaram maiores valores para proteína (P=0,007), lipídios (P=0,0001) e cinzas (P=0,0001) e baixo teor de carboidratos (P=0,011). Os *nuggets* apresentaram cor mais escura (P=0,0001) e maior dureza (P=0,0001) com o aumento da porcentagem de farinha de peixe na formulação. Os *nuggets* de farinha de peixe foram mais amplamente aceitos pelos consumidores. O ganho no valor nutricional dos *nuggets* e a aceitação positiva pelos consumidores (P=0,0001) demonstra que é possível substituir parcialmente a farinha de trigo pela farinha de peixe em produtos reestruturados tipo *nuggets*.

Palavras-chave: Resíduos de peixe, produto pronto para consumo, composição centesimal, parâmetros instrumentais, teste hedônico, análise CATA.

ABSTRACT

Although fish processing is an alternative to increasing fish consumption, about 30 to 40% of the fish is only used in the process, the remainder is discarded as residues such as head, carcass and viscera. The use of fish is an alternative for a better use of the raw material, adding value, elaborating new nutritious food products, increasing profitability, reducing input costs and reducing the amount of discarded at the end. The present work aims to use part of the discarded in fish processing to make a fish flour and use it in the partial replacement of the wheat flour of a restructured *nuggets* product to increase its nutritive value. Approximately ten kg of fish fillet were used to make the *nuggets* and two kg of fish pulp were used to make fish flour. The wheat flour (FT) used to pat the *nuggets* was partially replaced with fish flour (FF). Four formulations were tested: control T1 (100% FP), T1 (90% FT/10% FP), T2 (75% FT/25% FP) and T (60% FT/40% FP). Protein, lipids, ash, moisture, carbohydrate and energy value were analyzed to determine the chemical composition of the products. Instrumental analyzes of color and textures were performed to verify the physical characteristics of the *nuggets* and sensorial analysis to verify the acceptance of the product and the main characteristics perceived by consumers. The *nuggets* with the fish flour presented higher values for protein (P=0.007), lipids (P=0.0001) and ashes (P=0.0001) and low carbohydrate (P=0.011) content. The *nuggets* presented darker color (P=0.0001) and greater hardness (P=0.0001) with increasing percentage of fish flour in the formulation. The fish flour *nuggets* were more widely accepted by consumers over control. The gain in *nuggets* nutritional value and positive acceptance by consumers (P=0.0001) demonstrates that it is feasible to partially replace wheat flour with fish flour in restructured products.

Keywords: Fish, ready-to-eat product, centesimal composition, instrumental parameters, hedonic test, CATA analysis.

SUMÁRIO

1. Introdução

A produção de pescado é uma importante atividade econômica praticada em todo mundo. A produção mundial em 2014 foi de 167,2 milhões de toneladas de pescado, sendo 93,4 milhões (55%) produzidos pela pesca extrativa e 73,8 milhões de toneladas oriundas da aquicultura (FAO, 2016). Segundo a FAO (2016), 146,3 milhões de toneladas de pescado foram utilizados para a alimentação humana enquanto o restante, 20,9 milhões, foi utilizado para outros fins como produção de ração animal.

Os últimos dados de produção pesqueira no Brasil apontaram uma produção total de 1,4 milhões de toneladas, sendo aproximadamente 770mil toneladas oriundas de pesca extrativa (Brasil, 2013). O PIB gerado pela pesca foi de 5 bilhões de reais (Brasil, 2013). A atividade conta com aproximadamente 800 mil profissionais envolvidos e gera cerca de 3,5 milhões de empregos diretos e indiretos (MPA, 2013; Silva et al., 2015).

Dentre as fontes de proteína animal, a carne de pescado se destaca devido o seu valor nutritivo e sua alta digestibilidade no organismo humano (±95%) (Sartori & Anâncio, 2012). Segundo Sartori & Anâncio (2012), a qualidade da carne dos peixes varia de acordo com a espécie, ambiente, estágio da vida e nutrição. A carne de peixe é rica em proteínas, minerais, vitaminas (A, B e D), cálcio, ferro, fósforo, selênio, cobre, iodo (peixes marinhos) e ácidos graxos polinsaturados, que são essenciais para uma alimentação nutritiva e boa saúde, com baixo teor de carboidratos (Stevanato et al., 2007; Sartori & Anâncio, 2012; Monteiro et al., 2014; Palmeiras et al., 2016). Todos os aminoácidos essênciais para o ser humano são encontrados na proteína da carne de peixe (Sartori & Anâncio, 2012), sendo estes considerados alimentos nutracêuticos pelo seu valor nutritivo e capacidade de atuar na prevenção de doenças (Suarez- Mahecha et al., 2002), além de desempenharem um papel importante no desenvolvimento neural de crianças (Guiné & Henriques, 2011).

Dentre os ácidos graxos polinsaturados (PUFA's) essenciais encontrados no peixe, o tipo ômega-3 como, eicosapentaenóico (EPA) e docosaexaenóico (DHA) são os de principal destaque. O ômega-3 integra a membrana celular, atua como base para síntese de hormônios, na regulação da pressão arterial (Guiné & Henriques, 2011; Sartori & Anâncio, 2012) e em vários processos fisiológicos importantes como cicatrização, resposta imune e divisão celular (Guiné & Henriques, 2011). O consumo destes ácidos graxos pode reduzir o risco de doenças cardiovasculares, e níveis de colesterol, prevenção de câncer (Suarez- Mahecha et al., 2002; Sartori & Anâncio, 2012; Monteiro et al, 2014) e são essencialmente fornecidos pela dieta, uma vez que não são sintetizados pelo organismo humano (Stevanato et al., 2007). O consumo de porções de pescado que contendo em média dois gramas desses ácidos graxos por semana pode reduzir o risco de mal de Alzheimer, de acidente vascular cerebral (AVC) e depressão (Sartori & Anâncio, 2012).

1.1 Consumo de pescado no Brasil

Apesar do alto valor nutritivo dos peixes e seus benefícios para a saúde humana, o consumo de pescado no Brasil é um dos menores do mundo cerca de 9 kg/habitante por ano, enquanto a recomendação da Organização Mundial de Saúde (OMS) é de 12 Kg/habitante por ano (Souza et al., 2010; Silva et al., 2015). Este fato está relacionado com a falta do hábito de consumir pescado, falta de qualidade, variedade e praticidade de produtos a base de pescado (Bombardelli et al., 2005; Bochi et al., 2008). O tempo para a sua preparação e o preço também podem desencorajar alguns consumidores de comprar, levando a uma preferência por produtos prontos para cozinhar ou prontos a comer (Palmeiras et al., 2016).

Nos últimos anos, o Brasil vem apresentando mudanças no setor pesqueiro que resultaram em uma maior variedade de produtos como peixes filetados, hambúrgueres, peixes empanados, entre outros (Bochi et al., 2008). Segundo Centenaro et al. (2007), a oferta e diversificação de produtos à base de peixes marinhos incentiva o consumo de pescado.

1.2 Utilizações do resíduo do beneficiamento de pescado

Apesar do beneficiamento do pescado ser uma alternativa para o aumento de consumo de pescado, dependendo da espécie de peixe processada e do produto final, os resíduos gerados representam algo entre 8 a 16% em peixes eviscerados e 60 a 72% em peixes filetados (Kubitza, 2006; Godoy et al., 2013). Cabeças, escamas, peles, vísceras e carcaças (esqueleto com carne aderida) são os principais resíduos do processamento de pescado (Feltes et al, 2010; Fogaça et al., 2014). O não aproveitamento destes resíduos é um desperdiço de matéria prima rica em nutrientes, minerais ácidos graxos e proteínas (Feltes et al., 2010; Monteiro et al., 2014). Além disso, a quantidade gerada e a falta de destino adequado dos resíduos geram problemas de poluição impactando o ambiente (Kroyer, 1995; Guilherme et al., 2007).

Segundo Melo et al. (2011) a falta de um maior aproveitamento de resíduos de pescado é devido a falta de um conhecimento mais amplo em tecnologia de aproveitamento e técnicas sanitárias adequadas para conservação. Porém, nos últimos 20 anos tem chamado atenção pelo potencial de ser utilizado como uma importante fonte de adicional de nutrientes em dietas humanas (FAO, 2016). Nos últimos anos, as indústrias de alimentos buscam tecnologias de reciclagem de resíduos para diminuir a poluição ambiental e melhorar os ganhos econômicos devido aos altos custos de eliminação de resíduos (Castro-Muñoz et al., 2016).

No Brasil, o aproveitamento dos resíduos de pescado é pequeno devido principalmente à falta de conhecimento sobre a utilização deste recurso como matéria-prima e fonte para outros produtos alimentares humanos (Godoy et al., 2013). A utilização dos resíduos de pescado é uma alternativa para um maior aproveitamento da matéria prima, agregação de valor, elaboração de novos produtos alimentares nutritivos, aumento da lucratividade, redução de custos de insumos de produção e da quantidade de resíduo descartado (Kroyer, 1995; Bombardelli et al., 2005; Monteiro et al., 2014; Feltes et al., 2010; Melo et al., 2011).

Os resíduos de pescado são comumente mais utilizados na alimentação animal através da utilização de farinha e óleo de peixes utilizados para produzir ração (Feltes et al., 2010, FAO, 2016). Também podem ser utilizados na produção de fertilizantes, pigmentos naturais, produtos dietéticos (quitosina), produtos cosméticos a base de colágeno e até mesmo, biodiesel e biogás (Feltes et al., 2010; Jayathilakan et al., 2012). Diversos autores realizaram estudos demonstrando que o uso de resíduo de pescado tem potencial para ser utilizado na elaboração de alimentos humanos (Adekele & Idedeji, 2010; Feltes et al., 2010; Palmeiras et al., 2016, Monteiro et al., 2016; Kimura et al., 2017; Desai, et al., 2018).

Uma forma de aproveitamento do resíduo do pescado é a obtenção de polpa de peixe retirada da carcaça (Feltes et al., 2010; Palmeiras et al., 2016). A polpa de peixe apresenta potencial para ser utilizada em diversos produtos, além de servir como base para a produção de surimi e farinha de peixe (Feltes et al., 2010; Palmeiras et al., 2016, Monteiro et al., 2016). Melo et al. (2011) realizaram um estudo elaborando produtos com polpas de carne de resíduos de algumas espécies de peixes marinhos e seus resultados demonstraram que estas eram ricas em proteínas, fibras alimentares além de não conter gordura trans e uma baixa quantidade de carboidratos. Silva & Fernandes (2010), com a intenção de aproveitar peixes de baixo valor comercial desenvolveram um fishburguer de corvina, que teve uma boa aceitação, demonstrando que o aproveitamento de peixes de baixo valor na elaboração de produtos reestruturados comerciais é uma alternativa para o consumo de pescado.

A elaboração de produtos reestruturados permite o uso de resíduos de peixe na formulação (Jayathilakan et al., 2012; Monteiro et al., 2014). Além disso, a farinha de peixe é um ingrediente nutritivo que pode ser usado como substituto das farinhas convencionais em alimentos (Monteiro et al., 2016). Stevanato et al. (2007), desenvolveram uma sopa com farinha de cabeça de tilápia, relatando que o produto era uma fonte nutritiva e benéfica e teve uma grande aceitação nos testes sensoriais.

Atualmente, o consumo de alimentos empanados e reestruturados de diferentes substratos, incluindo peixe, aumentou significativamente (Nasiri et al., 2012). Os produtos reestruturados possuem características que geralmente atraem a atenção dos consumidores, aumentando a intenção de compras desses produtos (Monteiro et al., 2014). Estes produtos podem ser consumidos frito, resultando em gosto, aparência e textura que aumentam a aceitabilidade do produto, além de reduzir a degradação do produto (Nasiri et al., 2012). A camada de cobertura de produtos empanados apresenta uma textura crocante com cores atrativas ao consumidor além de atuar como uma barreira contra a perda de umidade e dos sucos naturais do substrato. A camada de cobertura também concede ao produto um revestimento crocante no exterior mantendo o interior suculento e macio (Albert et al, 2009; Nasiri et al., 2012).

Estes produtos são fontes de proteína que podem ser produzidos com peixes de baixo valor comercial e subexplotados, representando uma alternativa rentável para a indústria alimentícia (Perlo et al., 2006; Jayathilakan et al., 2012). O processamento deste tipo de produto possui um menor custo de produção e resulta em produtos padronizados, seguros e com boa aparência, além de serem práticos no preparo final. Essas características acompanham as mudanças dos atuais perfis dos padrões de consumo de proteína animal no mundo (Almeida et al., 2015).

Na literatura, diversos estudos relatam elaboração de produtos com utilização de farinha de peixe, relatando ganho nutritivo na elaboração de macarrão (Goes et al., 2016; Monteiro et al., 2016; Kimura., 2017; Desai et al., 2018), sopas (Monteiro et al., 2014) pães (Dalton et al., 2009; Adekele & Idedeji, 2010), biscoitos (Justen et al., 2017) entre outros (Kimura et al., 2017). Estes trabalhos demonstram que o aproveitamento do subproduto do processamento de pescado vem sendo explorado mundialmente, no entanto, medidas a respeito de suas consequências econômicas e ambientais devem ser consideradas.

1.3 Priacanthus arenatus - Cuvier 1829 – *Olho de Cão ou Mirasol*

Priacanthus arenatus, um peixe marinho da família *Priacanthidae,* comumente chamada de Olho de Cão ou Mirasol, pode ser encontrada desde o Atlântico ocidental do Canadá até a Argentina, ocorrendo em todo litoral brasileiro. Pode ser encontrado individualmente ou em pequenos cardumes em profundidades que variam de cinco até 130 metros de profundidade. São encontrados próximos a fundos rochosos e corais (Ximenes-Carvalho et al., 2009; Froese & Pauly, 2016).

Sua carne é considerada de excelente sabor e bem aceita para consumo, sendo comercializado e consumido no Sudeste e Nordeste do país (Ximenes-Carvalho et al., 2009; Soares et al., 2013; Froese & Pauly, 2016), porém apresenta uma baixa participação na produção pesqueira do Brasil, cerca de 0,03% em 2011 (200 toneladas) (Brasil, 2013). Esta espécie é uma opção de explotação na atual crise da pesca comercial de pescado no Brasil (Freire et al., 2016).

A espécie possui o dorso de cor avermelhada com reflexos dourados e o ventre branco. Corpo comprido e comprimido lateralmente, olhos e bocas grandes. Apresenta uma pequena espinha na parte inferior do pré-opérculo e escamas ctenóides de espessura fina. Seu comprimento pode chegar até 50 cm e peso de até três quilos, mas na média seu tamanho é de 25 cm com até 800 gramas (Ximenes-Carvalho et al., 2009; Froese & Pauly, 2016). É um peixe carnívoro e de hábitos noturnos. Alimentam-se de pequenos peixes, crustáceos, lulas e poliquetas (Ximenes-Carvalho et al., 2009; Froese & Pauly, 2016; Kuraiem et al., 2016).

Priacanthus arenatus é uma das espécies de peixe marinho exploradas para processamento para produção de hambúrguer, almôndega, quibe e *nuggets* para comercialização na região dos Lagos – RJ, Brasil pela cooperativa de pescadoras “Mulheres Nativas de Arraial do Cabo”. No entanto, existem poucos trabalhos científicos que descrevam sobre a elaboração de subprodutos do processamento desta espécie.

Figura 1-*Priacanthus arenatus***,** Cuvier 1829. Fonte: *fishbase.de*

1.4 Estrutura da Dissertação

A dissertação é composta de um artigo científico a ser submetido a princípio à revista *Journal Food Science* & *Techonology*.

2. Objetivos

2.1 Objetivo geral

Elaborar *nuggets* com o filé do peixe e usar diferentes percentuais de substituição parcial da farinha de trigo pela farinha de peixe *Priacanthus arenatus* feita com a polpa da carcaça do peixe.

2.2 Objetivos específicos

- Elaborar a farinha com polpa retirada da carcaça do peixe *P. arenatus*;
- Elaborar *nuggets* com o filé do peixe e usar diferentes percentuais de substituição parcial da farinha de trigo pela farinha de peixe *P. arenatus* na massa de empanar e compara-los;
- Realizar a composição centesimal e análise instrumental de cor e textura dos *nuggets*;
- Realizar a avaliação sensorial, através dos testes de aceitação, intenção de compra e check-all-that-apply (CATA).

3. Hipótese

Maiores percentagens de farinha do *P. arenatus* na elaboração de *nuggets* favorecerão um alimento mais rico nutricionalmente e com sabor mais marcante, quando comparado aos *nuggets* com farinha de trigo.

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5. Nutritional improvement and consumer perspective of fish *nuggets* with partial substitution of wheat flour coating by fish (*Priacanthus arenatus*) flour

ABSTRACT

Pre-fried and fried fish nugget formulations with partial replacement of wheat flour (WF) coating by fish waste flour (FF) were investigated in relation to proximate composition, instrumental color parameters, instrumental texture profile, and sensory attributes (characterization and acceptance). Four formulations were prepared as follow: control (100% WF), T1 (90% WF + 10% FF), T2 (75% WF + 25% FF), and T3 (60% WF + 40% FF). Regardless pre-frying and frying processes, T3 had higher ($P < 0.05$) protein, lipid and ash contents, while lower ($P < 0.05$) carbohydrate level than their control counterparts. Overall, T2 and T3 increased ($P < 0.05$) h° angle, a^* and b^* values in both pre-fried and fried fish nugget. T2 and T3 exhibited lower ($P < 0.05$) hardness and chewiness under pre-fried condition, however, it was higher ($P < 0.05$) in these same fried formulations. FF increased ($P < 0.05$) perception of dark golden color, fish flavor, and crunchy. T2 and T3 received higher ($P < 0.05$) scores for acceptance and preference than their control counterparts. The replacement of WF coating by FF at 40% enhanced the nutritional value and sensory acceptance/preference of fish nuggets representing a potential strategy to health market.

Keywords: fish by-products, ready-to-cook product, instrumental color, texture profile, CATA analysis.

Introduction

Marine fish are food sources highly nutritive rich in essential fatty acids such as eicosapentaenoic (EPA) and docosahexaenoic (DHA) which reduce the risks of cardiovascular diseases, several types of cancers, hypertension and other diseases contributing for global food security (Palmeiras et al, 2016). Due to this fact, fish production has continuously increased at an average annual rate of growth of 3.2% generating a great amount of s, which constitutes 70% of the total fish weight and are discarded impacting the environment (FAO, 2016).

Therefore, recently, food industries have been looking for recycling technologies to reduce environmental pollution and improve economic gains due to high disposal costs (Castro-Muñoz et al., 2016). Among marine fish species, *Priacanthus arenatus* have been drawing attention due to great flavor and good acceptability, presenting a great potential for exportation (Soares et al., 2011; Froese & Pauly, 2016).

Nevertheless, although the high nutritional value of the fish, the time for their preparation, limited shelf life and price may discourage some consumers to purchase, leading to a preference for ready-to-cook or ready-to-eat products (Palmeiras et al., 2016). Among these ready-to-eat products, pre-fried frozen foods from different matrix (meat, chicken or fish) are very appreciated by most consumers, especially *nuggets* which have a low cost of production, easy preparation, prolonged shelf life, and are a good vehicle for application of nutritionally enriched ingredients (Xiao et al., 2011; Barbut et al., 2012; Nasiri et al., 2012).

Nuggets are usually produced with wheat flour coating (Sahin et al., 2005; Teruel et al., 2015), which is poor in protein and rich in carbohydrates, mainly starch highly digestible with high glycemic index (GI) (Baljeet et al., 2010; Sui et al., 2016; Han & Koh, 2011), thereby increasing risk of some diseases such as diabetes and biliary tract cancer (Askari et al., 2013; Larsson et al., 2016). On the other hand, fish flour is a cheap source of high-quality nutrients from fish processing, which have easy preparation and represent a potential substitute for conventional flours commonly used in breaded products (Stevanato et al., 2010; Monteiro et al., 2014; Teruel et al., 2015).

Some authors have been reported successful replacement of wheat flour coating by nutritionally enriched ingredients such as oat flour and rice bran in chicken *nuggets* (Maliluan et al., 2013; Santhi & Kalaikannan, 2015). However, to the best of our knowledge, there are no studies regarding nutritional composition and consumer perspective of fish *nuggets* enriched with fish flour coating, which is important to encourage the healthy foods market based on fish from processing. In addition, information about fish *nuggets* is limited in literature.

Considering the increasing consumption of convenient/healthy foods with pleasant sensory qualities, the aim of this study was to characterize fish *nuggets* manufactured with different levels of fish (*Priacanthus arenatus*) flour in substitution to wheat flour coating under different presentation forms (pre-fried and fried) from the point of view of the nutritional value, instrumental color and texture parameters, and sensory attributes by a consumer-based approach.

Materials and methods

Sample obtaining

Approximately 35kg of whole fish (*Priacanthus arenatus*) was purchased directly from fishing boat at Arraial do Cabo, Rio de Janeiro, Brazil. The fish were washed, gutted, head and tail removed, filleted, and then the remaining was passed through a meat separator machine for obtaining of fish pulp. Approximately 12.5kg of fish fillet and 2kg of fish pulp were packed in plastic bags, frozen, and transported in ice to the laboratory within 3 hours. The fish flour (FF) was manufactured following method proposed by Monteiro et al. (2014).

Nuggets preparation

The *nuggets* were formulated according to Teruel et al. (2015) with slight modifications following commercial conditions for pre-fried products: 60% fish fillet, 23% ice, 15% potato flakes (Lutosa, Leuze-en-Hainaut, Belgium), 1% salt (Cisne®, Rio de Janeiro, Brazil) and 1% albumin (Salto’s, São Paulo, Brazil). The ingredients of mass of *nuggets* were homogenized in a multiprocessor, the *nuggets* were shaped (5cm diameter x 1cm height), and then weighted (approximately 25g each). The *nuggets* were divided into four treatments and were dipped in a four formulated batter containing 93.57% of white wheat flour (Boa Sorte, Paraná, Brazil) and FF in different ratios, 1.17% of salt (Cisne®, Rio de Janeiro, Brazil), 0.24% of bicarbonate (Kitano, Paraná, Brazil), 2.34% of yeast (Armazem, Rio de Janeiro, Brazil), 1.17% of xanthan gum (Pluri, São Paulo, Brazil), and 1.51% of ice water (Table 1).

Table 1. Formulated batter of fish *nuggets* manufactured with different levels of fish (*anthus arenatus*) flour coating in substitution to wheat flour.

	Formulations[¥]			
Ingredients	Control	T1	T2	T3
Wheat flour (g)	561.42	505.28	421.06	336.85
Fish flour (g)	0.00	56.14	140.36	224.57
Salt (g)	7.02	7.02	7.02	7.02
Bicarbonate (g)	1.44	1.44	1.44	1.44
Yeast (g)	14.04	14.04	14.04	14.04
Xanthan gum (g)	7.02	7.02	7.02	7.02
Ice water (ml)	9.06	9.06	9.06	9.06

[¥]Control (100% of wheat flour), T1 (90% of wheat flour + 10% of fish flour), T2 (75% of wheat flour + 25% of fish flour), and T3 (60% of wheat flour+ 40% of fish flour).

A total of 480 *nuggets* were produced (120 for each treatment). All *nuggets* were pre-fried in oil (Liza, São Paulo, Brazil) at 165°C for 30 seconds. The average internal temperature was 29.5°C, which was measured after pre-frying using a digital thermometer (HOMUS, Mod 406). After cooling, the *nuggets* were placed in plastic bags and frozen at -18ºC. One part of the pre-fried *nuggets* of each treatment was taken from freezer and immediately fried at 165°C for 3 minutes until reach an internal temperature above 72°C (Teruel et al., 2015). Both pre-fried and fried *nuggets* were analyzed for proximate composition, energy value, instrumental color parameters, and instrumental texture profile. Moreover, sensory evaluation was also carried out in fried *nuggets* formulations.

(a)

(b)

Figure 2- Pre-fried *nuggets* (a) and fried *nuggets* (b).

Proximate composition

The moisture (AOAC, method 950.46B), ash (AOAC method 920.153), protein (AOAC method 955.04), and lipid (AOAC method 991.36) contents were determined according to the procedures of the Association of Official Analytical Chemists (AOAC, 2012). The carbohydrate level was calculated by equation % carbohydrates = 100% − (% moisture + % protein + % ash + % lipid), while the energy value was determined following the formula energy value (kcal/100g) = 4 × protein (%) + 9 × lipid (%) + 4 × carbohydrate (%) (Merrill & Watt, 1973). These analyses were performed in triplicate.

Instrumental color measurement

CIE *L** (lightness), *a** (redness) and *b** (yellowness) values were recorded through a Minolta CM-600D Spectrophotometer (Minolta Camera Co., Osaka, Japan) utilizing illuminant D65, 8 mm aperture, and 10° observer at 25°C. Chroma (*C**) and hue angle (h°) were calculated from chromaticity coordinates (*a** and *b**) following formula described in American Meat Science Association (AMSA, 2012). The color measurements were carried out in ten replicates on two sides of each *nuggets*, totaling 20 measures for each treatment.

Instrumental texture measurement

Texture profile analysis (TPA) was determined utilizing a texture analyzer model TA.XT plus (Stable Micro System, Surrey, UK) coupled to texture expert software following recommendations of Bourne (1978). Each *nuggets* was compressed using a P/36R probe with two compression cycles, interval time between compressions of 5s, vertical strain of 40%, and probe speed of 5 mm/s (before, during and after test). TPA was performed in ten replicates of each treatment.

Consumer study

Participants

The present study was approved by the Research Ethics Committee of the Universidade Federal Flumimense (protocol number 51115215.0000.5243/2016, Niterói, Rio de Janeiro, Brazil). One hundred fifty one consumers were randomly recruited in a University located in the Rio de Janeiro, Brazil. All participants had a habit of consuming fish and/or fish products and, before participation in the study, they signed a consent form. The socio-demographic profile of the participants is exhibited in Table 2.

Table 2. Demographic characteristics of the participants (n = 151).

Characteristics	%
Gender	
Female	68.87
Male	31.13
Age (years)	
18–25	74.83
26–35	14.57
36–45	5.96
46–55	3.31
56–65	1.32
66 and older	0.00
Education	
Incomplete high school	0.66
Complete high school	0.00
Incomplete undergraduate	0.00
Complete undergraduate	6.62
Incomplete graduate	72.85
Complete graduate	5.96
Postgraduate	13.91
Household income[¥]	
1–5	50.99
> 5–10	33.11
> 10–20	11.26
> 20–30	1.99
> 30	0.66

[¥]The household income was based on Brazilian monthly minimum wage (BMW; $ 297 in August 2017).

Sample preparation

The sensory evaluation was performed with fried *nuggets* formulations prepared under conditions described above. Each *nuggets* formulation was cut into two pieces and placed in oven with temperature-controlled room to maintain *nuggets* at 35-40°C. Samples were served in plastic glasses, labeled with 3-digit random codes, and monadically presented to participants in a balanced order. Filtered water at room temperature (23–25°C) were available for cleanse the palate between samples.

Experimental procedure

The sensory evaluation was composed of acceptance test and purchase intention (Stone & Sidel, 2004), descriptive analysis through check-all-that-apply (CATA) questions (Ares et al., 2014), and a final question regarding consumer interest in eating a product with high content of proteins and minerals. In the acceptance test, the participants evaluated the overall liking of each *nuggets* formulation in a nine-point structured hedonic scale (1 = dislike extremely to 9 = like extremely). Participants also scored their purchase intention in a seven-point structured scale ranging from 1 = would always buy to 7 = would never buy.

The CATA terms used in this study were previously defined by 8 students with experience in sensory research during a tasting session using all *nuggets* formulations evaluated in this study (control, T1, T2, and T3). The sensory CATA terms were weak fish *nuggets* aroma, strong fish *nuggets* aroma, dry texture, acid aftertaste, crumbly, homogeneous mass, brittle mass, light golden color, dark golden color, salty taste, weak fish *nuggets* flavor, strong fish *nuggets* flavor, bitter aftertaste, metallic flavor, juicy, crunchy, gummy and soft. The CATA terms were included in the questionnaire in a balanced way for each sample and each participant (Ares et al., 2014). Finally, participants responded “yes” or “no” to a final question: “Would you be interested in eating *nuggets* with a higher amount of proteins and minerals?”.

Statistical analyses

One-way ANOVA followed by Tukey test ($P < 0.05$) was used for comparison between means of proximate composition, energy value, and hedonic scores (acceptance test and purchase intention). Internal Preference Mapping was carried out to detect consumer preferences among the different formulations. The frequency of mention of each CATA term for each *nuggets* formulation was analyzed by Correspondence

Analysis (CA), and significant terms ($P < 0.05$) were detected by Cochran's Q test. In addition, Multifactorial Analysis (MFA) was performed to verify the parameters that were influenced by FF. The demographic data and the final question were evaluated by frequency of each response. All statistical analyses were carried out through a XLSTAT software, version 2012.6.08 (Addinsoft, New York, NY, USA) with a confidence interval at 95%.

Results and Discussion

Proximate composition

The results of proximate composition and energetic value of the pre-fried and fried *nuggets* formulations are exhibited in Table 3. The protein result showed a siginicative difference between treatments (ANOVA; F=11.148; P=0.018). T3 and T2 did not present a difference between them (P=0.070), but T3 was different from T1 (P=0.041) and control (P=0.017). There was no significant difference between control, T1 and T2 (P=0.091). For the lipid values, the results showed present a siginicative difference (ANOVA; F=9.430; P=0.017). T3 and T2 did not present a siginicative difference between them (P=0,417), but T3 was different from T1 (P=0.045) and control (P=0.017) and there was no difference between control, T1 (P=0.885) and T2 (P=0.098). The *nuggets* also presented siginicative difference in the results for ash values (ANOVA; F=10.865; P=0.003). T3 presented the highest ash content (P=0.003), while the control, T1 and T2 did not differ significantly between themselves. The moisture (ANOVA; F =2.281; P=0.127) and energetic value (ANOVA; F=1.367; P=0.373) did not differ significantly between treatments. The carbohydrate values also showed difference between the treatments pré-fried (ANOVA; F=15.475; P=0.011 Control and T1 were the highest values and presented no difference between them (P=0.131), but control presented difference with T2 (P=0.045) and T3 (P=0.009). There was no difference between treatments T1, T2 and T3.

In relation to fried *nuggets* formulations, the content of protein (ANOVA; F=11.148, P=0.007) exhibited significant difference in their results. T3 and T2 did not present a difference between them (P=0.070), but T3 was different from T1 (P=0.015) and control (P=0.008). There was no significant difference between control, T1 (P=0.999) and T2 (P=0.497). The treatments also presented difference for the lipid values (ANOVA; F=31.511; P=0.0001). T3 and T2 had the higher values for lipid and had no siginicative difference between them (P=0.062), but T3 was different from T1 ($P < 0.05$)

and control. (ANOVA; P< 0.05). Control demonstrated lower lipid levels than T2 (ANOVA; F=31.51; P=0.008) and T3 (ANOVA; F=31.51; P=0.0001). There was no significant difference between control and T1 and T1 and T2 (P=0.60). T3 presented the highest energy value (ANOVA; F=31.23; P≤0.05) in relation to the other treatments. T2 and T1 presented no difference between them (P=0.647). Control was different from T3 (P<0.05) and T2 (P=0.005), but did not present difference in relation to T1 (P=0.107). The inclusion of fish flour also significantly affected (ANOVA; F=41.002; P=0.0001) the carbohydrate values in the fried *nuggets*. T3 was the lowest carbohydrate content and was significantly different in relation to the other treatments (P=0.0001). There was no difference between T2 and control treatment (P=0.149), but T2 presented difference with T1 (P=0.033). There was no difference between the values of T1 and control carbohydrates (P=0.416). The moisture results showed no significant difference (ANOVA; F=2.843; P=0.115) between them.

Table 3. Proximate composition (%) of *nuggets* fortified with different levels of *P. arenatus* flour.

Parameters	Pre-fried formulations[¥]			
	Control	T1	T2	T3
Protein	14.06 ± 0.12^{b}	14.79 ± 0.98^{b}	15.99 ± 0.25^{ab}	17.28 ± 0.54^{a}
Lipids	3.43 ± 0.15^{b}	3.48 ± 0.28^{b}	3.89 ± 0.24^{ab}	$4.22\pm\text{-}0.07^{a}$
Ash	2.05 ± 0.03^{b}	2.00 ± 0.05^{b}	2.05 ± 0.03^{b}	2.18 ± 0.01^{a}
Moisture	62.98 ± 0.31^{a}	64.45 ± 1.06^{a}	64.36 ± 0.68^{a}	64.96 ± 1.38^{a}
Carbohydrates	17.65 ± 0.17^{a}	15.14 ± 1.27^{b}	14.05 ± 0.46^{b}	11.94 ± 1.03^{b}
Energy value	157.84 ± 0.03^{a}	151.05 ± 3.66^{a}	155.17 ± 0.73^{a}	154.87 ± 5.63^{a}
Parameters	Fried formulations[¥]			
	Control	T1	T2	T3
Protein	16.24 ± 0.48^{b}	16.35 ± 0.47^{b}	17.76 ± 0.83^{ab}	21.00 ± 1.75^{a}
Lipids	7.38 ± 0.43^{c}	8.45 ± 0.51^{bc}	10.25 ± 0.51^{ab}	12.03 ± 1.02^{a}
Ash	2.47 ± 0.01^{b}	2.42 ± 0.05^{b}	2.45 ± 0.06^{b}	2.66 ± 0.04^{a}
Moisture	55.40 ± 0.43^{a}	53.36 ± 0.67^{a}	52.82 ± 0.75^{a}	51.80 ± 2.54^{a}
Carbohydrates	18.35 ± 0.37^{ab}	19.42 ± 1.18^{a}	16.72 ± 0.66^{b}	13.14 ± 0.66^{c}
Energy value	205.39 ± 3.79^{c}	219.20 ± 2.91^{bc}	230.17 ± 5.30^{b}	246.87 ± 8.07^{a}

[¥]Control (100% of wheat flour), T1 (90% of wheat flour + 10% of fish flour), T2 (75% of wheat flour + 25% of fish flour), and T3 (60% of wheat flour + 40% of fish flour). Results are expressed as means ± standard deviation. Different superscripts indicate significant differences ($p < 0.05$) among formulations.

The addition of fish flour in both pre-fried and fried *nuggets* formulations resulted in an increase of protein, lipid and ash contents, and lowering of carbohydrate levels. This fact may be attributed to different composition of wheat flour and fish flour. Fish flour is rich in protein, lipid and ash, and poor in carbohydrates (Monteiro et al., 2014; Goes et al., 2016; Desai et al., 2018). In contrast, wheat flour has high amount of carbohydrates, and low levels of protein, lipid and ash (Desai et al., 2018). Our results of energy value can be explained by the changes in the lipid, protein, and carbohydrate levels caused by fish flour addition in association to their respective individual weights in the formula proposed by Merrill and Watt (1973). Similarly, Monteiro et al. (2016) and Desai et al. (2018) also found the same trend in energy value of pasta enriched with tilapia flour and cod flour, respectively.

There are no studies evaluating nutritional value of *nuggets* manufactured with partial replacement of wheat flour coating by fish flour. In agreement with our findings, other authors reported similar pattern on proximate composition and energy value in instant soup and pasta enriched with tilapia flour (Monteiro et al., 2014; Monteiro et al., 2016), lasagna fortified with tuna flour and tilapia flour (Kimura et al, 2017), bread manufactured with tilapia flour (Adekele & Odedeji, 2010; Monteiro et al., 2018), and pasta enriched with cod flour (Desai, et al., 2018).

Instrumental color measurement

The values *L** (lightness), *a** (redness) and *b** (yellowness) *C** (Chroma) and h° (hue angle) are shown in Table 4. No difference ($P > 0.05$) was observed in L* values among all treatments in both pre-fried (ANOVA; F=2.135; P=0.10) and fried *nuggets* formulations (ANOVA; F =0.804; P=0.048). There was a significant difference of *a** (ANOVA; F =22.299; P=0.0001), *b** (ANOVA; F=48.908; P=0.0001) and *C** (ANOVA; F =38.287; P=0.0001) among pre-fried treatments. T2 presented a difference in the value of *a** in relation to control (P=0.0001) and T1 (P=0.0001), but did not differ from T3 (P=0.738). The T3 treatment also presented difference with the control (P=0.0001) and T1 (P=0.001). There was no difference between control and T1 (P=0.666). Regarding the results of the *b** values of the treatments, T2 presented a difference in the value in relation to the control (P=0.0001) and T1 (P=0.0001), but did not differ from T3 (P=0.104). The T3 treatment also presented difference with the control (P=0.0001) and T1 (P=0.0001). There was no difference between control and T1 (P=0.671). The values of *C** are directly related to the values of *L**, *a** and *b**. Thus, the *C** result of the treatments followed the same tendency of the results of *a** and *b**, where T2 presented difference in value in relation to control (P=0.0001) and T1 (P=0.001), but did not differ from T3 (P=0.993). There was no difference between the control and T1 treatments (P=0.723). And the T3 treatment presented difference with the control (P=0.0001) and T1 (P=0.000). There was a significant difference of h° between pre-fried treatments (ANOVA; F =80.681; P =0.0001). Control and T1 presented higher mean values, not differing from each other (P =0.999), while T2 and T3 did not differ among themselves, presenting lower mean values (P =0.559).

The pre-fried and fried *nuggets* formulations with partial replacement of wheat flour coating by FF were darker. Color changes by adding fish flour can be attributed to the visual difference between wheat and fish flours. The fish flour has a dark color due to the temperature used during the fish pulp drying process (Oliveira et al., 2015), and refined wheat flour have white color (Mellado-Ortega & Hornero-Méndez, 2016). Reinforcing our findings, previous studies have confirmed that substitution of wheat flour for fish flour resulted in higher values of *a** and *b** resulting in darkening of the product (Nurul et al., 2009; Monteiro et al., 2016; Goes et al., 2016).

In relation to fried *nuggets* formulations, there was a significant difference *a** (ANOVA; F=68.645; P=0.0001), *b** (ANOVA; F=4.815; P=0.005) e h^{o} (ANOVA; F=28.163; P=0.0001) between treatments. T3 exhibited the highest *a** values (P=0.0001) and the lowest h° values (P=0.0001). T2 and T1 presented no difference in the values of *a** (P=1.00) and hº (P=0.931). The control obtained the lowest value and was different from the other treatments (P=0.0001). There was a significant difference of *b** (ANOVA; F =4.815; P=0.005). Control presented the lowest *b** values (P=0.005), and no difference was observed in *b** values among T1, T2 and T3 (P=0.993). *L** (ANOVA; F=2.804; P=0.048) and *C** (ANOVA; F=0.314; P=0.815) values were similar in all fried *nuggets* formulations.

Table 4. *L** (lightness), *a** (redness), *b** (yellowness), *C** (chroma) and h° (hue angle) values of fish *nuggets* manufactured with different levels of fish (*Priacanthus arenatus*) flour coating in substitution to wheat flour.

Parameters	Pre-fried formulations[¥]			
	Control	T1	T2	T3
*L**	70.28±2.23[a]	69.77±2.59[a]	68.60±3.78[a]	69.69±3.88[a]
*a**	1.57±0.15[b]	1.61±0.09[b]	4.67±0.44[a]	4.28±0.46[a]
*b**	20.49±1.81[b]	20.70±2.01[b]	26.16±2.46[a]	25.17±2.52[a]
*C**	45.23±2.09[b]	48.21±3.26[b]	58.65±2.26[a]	57.63±0.65[a]
h°	85.84±0.39[a]	85.80±0.39[a]	80.89±0.72[b]	81.38±0.80[b]
Parameters	Fried formulations[¥]			
	Control	T1	T2	T3
*L**	62.82±4.09[a]	58.26±4.09[a]	58.72±3.05[a]	60.15±4.26[a]
*a**	10.26±0.99[c]	13.83±1.30[b]	13.18±1.09[b]	19.11±1.49[a]
*b**	34.26±2.77[b]	38.08±2.07[a]	38.24±1.66[a]	38.12±1.46[a]
*C**	81.41±2.90[a]	83.00±4.75[a]	82.22±1.49[a]	82.01±3.30[a]
h°	74.74±0.94[a]	71.03±1.25[b]	70.34±1.57[b]	63.15±2.88[c]

[¥]Control (100% of wheat flour), T1 (90% of wheat flour+ 10% of fish flour), T2 (75% of wheat flour + 25% of fish flour), and T3 (60% of wheat flour+ 40% of fish flour).
Results are expressed as means ± standard deviation. Different superscripts indicate significant differences ($P < 0.05$) among formulations.

The increase of *a** values decreased h° values in a gradual manner in both pre-fried and fried *nuggets* formulations. According to AMSA (2012), greater h° values indicates lower *a** values, corroborating with our findings. The hue angle (h°) indicates the perceptible color based on diagram of four colors wherein the red color is represented by the angles of 0° and 360°, the yellow color by an angle of 90°, the color green by angle of 180° and the blue color represented by the angle of 270°. On the other hand, the *C** (chroma) means saturation index or hue intensity, therefore, greater *C** values indicate a more perceptible color (AMSA, 2012; Pathare et al., 2013). The values h° and *C** are specific color parameters used to characterize and compare objectively meat products (AMSA, 2012), however, it is a recent approach in academic studies, making difficult to compare our results with published studies in the literature.

Our study demonstrated that in the pre-fried *nuggets* formulations, control and T1 had a pale yellow color. However, T2 and T3 showed a conversion from pale yellow color to more vivid orange-yellow color. In the fried *nuggets* formulations, control showed an orange-yellow color pattern, which tended to orange color in T1 and T2, and red color in T3. All fried *nuggets* formulations had vivid color.

Instrumental texture measurement

The results of hardness, springiness, cohesiveness, chewiness, and resilience are exhibited in Table 5. There was no difference in springiness (ANOVA; F=1.155; P=0.350), cohesiveness (ANOVA; F=1.046; P=0.400), and resilience (ANOVA; F=1.499; P=0.236) amongst all treatments in both pre-fried formulations. There was a significant difference of hardness (ANOVA; F=12.840; P=0.0001) and chewiness (ANOVA; F=41.877; P=0.0001). In the formulations of pre-fried *nuggets*, T2 and T3 were the lowest values and did not present difference for hardness and (P=0.376) and chewiness (P=0.297). The control and T1 that also did not present differences for hardness (P=1.00) and chewiness (P=0.987), but differed from T3 and T2 (P=0.001).

There was no difference in springiness (ANOVA; F=2.080; P=0.126), cohesiveness (ANOVA; F=0.613; P=0.612), and resilience (ANOVA; F=0.220; P=0.882) amongst all treatments in both fried formulations. There was a significant difference of hardness (ANOVA; F=44.550; P=0.0001) and chewiness (ANOVA; F=37.213; P=0.0001) between treatments fried. Regarding fried *nuggets* formulations, T3 had the highest hardness (P=0.0001) and chewiness (P=0.002). T2 presented an intermediate value of hardness, but did not differ from T1 (P = 0.275). For chewing, T2 also presented an intermediate value and if it was different from control (P=0.003) and T1 (P=0.029). Control and T1 presented no difference for hardness (P=0.515) and chewing (P=0.662).

Table 5. Instrumental texture parameters of fish *nuggets* manufactured with different levels of fish (*Priacanthus arenatus*) flour coating in substitution to wheat flour.

Parameters	Pre-fried formulations[¥]			
	Control	T1	T2	T3
Hardness (N/cm)	124.97±7.39[a]	127.60±3.977[a]	96.35±8.55[b]	84.93±7.02[b]
Springiness (cm)	0.985± 0.011[a]	0.985±0.028[a]	0.985±0.016[a]	0.971±0.007[a]
Cohesiveness (ratio)	0.615±0.043[a]	0.600±0.039[a]	0.640±0.50[a]	0.640±0.026[a]
Chewiness (N/cm)	56.32±2.90[a]	54.07±5.17[a]	26.88±5.61[b]	34.48±4.22[b]
Resilience (ratio)	0.355±0.026[a]	0.343±0.018[a]	0.351±0.031[a]	0.335±0.013[a]
Parameters	**Fried formulations[¥]**			
	Control	T1	T2	T3
Hardness (N/cm)	213.34±16.59[c]	226.75±19.45[bc]	251.65±15.87[b]	338.62±27.82[a]
Springiness (cm)	0.993±0.010[a]	0.984±0.009[a]	0.993±0.008[a]	0.986±0.007[a]
Cohesiveness (ratio)	0.613±0.032[a]	0.648±0.046[a]	0.641±0.064[a]	0.637±0.036[a]
Chewiness (N/cm)	136.43±14.13[c]	146.71±11.13[c]	174.91±17.86[b]	221.05±20.79[a]
Resilience (ratio)	0.439±0.022[a]	0.454±0.037[a]	0.457±0.045[a]	0.440±0.038[a]

[¥]Control (100% of wheat flour), T1 (90% of wheat flour + 10% of fish flour), T2 (75% of wheat flour + 25% of fish flour), and T3 (60% of wheat flour+ 40% of fish flour). Results are expressed as means ± standard deviation. Different superscripts indicate significant differences ($P < 0.05$) among formulations.

The combination of different flours directly influence on the texture of the final product (Nasiri et al., 2012; Chen & Opara, 2013), which depends mainly on product composition, proportion of ingredients and their water binding capacity as well as internal temperature of the product (Chen & Opara, 2013). During heating, starch gelatinization and evaporation of water cause changes in the food structure, increasing the firmness of flour-coated food products (Lund & Lorenz, 1984; Li et al., 2014; Velez-Ruiz et al., 2002; Rahimi & Ngad, 2016). However, the starch gelatinization process depends mainly on starch-protein ratio, temperature-time combination and protein integrity (Rahimi & Ngad, 2016; Coker et al., 2016; Desai et al., 2018). There are lacks of studies focusing in the behavior of starch-meat protein interactions at different temperature/time combinations. Nonetheless, it is known that the starch may protect the protein against thermal denaturation (Li et al., 2014). Moreover, the presence of macronutrients such as proteins compete with the starch for water impairing the swelling and gelatinization of the starch thereby decreasing the dough hardness (Lund & Lorenz, 1984; Li et al., 2014; Rahimi & Ngad, 2016), which explain our findings related to pre-fried *nuggets* formulations. Similarly, the hardness decreased as the level of fish flour increased in cassava cracker (Coker et al., 2016) and in noodles (Chin & Yang, 2012).

The fried *nuggets* had a longer time/temperature combination than the pre-fried *nuggets*. Therefore, our hypothesis is that a more intense thermal treatment resulted in protein denaturation and exposure of their hydrophobic groups (Shimada & Cheftel, 1989), thereby allowing starch-water binding and starch gelatinization. In addition, the denatured proteins induce intra-and intermolecular cross linking forming an insoluble network, which entrap gelatinized starch granules increasing hardness of the product (Martens et al., 1982; Desai et al., 2018). These facts may explain the increased hardness in the fried *nuggets* formulations containing the highest protein level (T2 and T3) in comparison with control. In agreement with our findings, Desai et al. (2018) and Chambó et al. (2017) reported that high replacement of fish flour by wheat flour increased the hardness of pasta and bread, respectively.

Sensory study

Consumer acceptance

There was a significant difference in overall taste between treatments (ANOVA; F=6.112; P=0.000). The control treatment had the lowest acceptance value, being different from T3 (P=0.001) and T2 (P=0.003), but did not present a difference with T1 (P=0.113). T3, T2 and T1 presented no difference between them (Table 6). Restructured fried products such as *nuggets* usually have attractive characteristics of flavor, appearance and texture (Nasiri et al., 2012)

However, there are lacks of studies regarding acceptance of fried *nuggets* manufactured with fish flour coating. There was no difference (P>0.05) among formulations for purchase intention (Table 6). Although acceptance strongly contributes to purchase intention, this parameter depends on other factors such as price and functional properties of the products (Shaviklo, 2013). In agreement with our findings, Bastos et al. (2014) reported the highest acceptance for breads formulated with 10% and 20% of fish flour, however, no difference was observed in purchase intention between breads with high-in-protein flour and control breads (without fish flour). Likewise, Goes et al. (2016) showed greater acceptance for pasta with 20% of fish flour and no difference in purchase intention between fortified pasta and non-fortified pasta.

Table 6. Average overall liking, purchase intention scores and frequency (%) of the CATA terms used for all fish *nuggets* manufactured with different levels of fish (*Priacanthus arenatus*) flour coating in substitution to wheat flour.

Terms	Formulations¥			
	CON	T1	T2	T3
Overall liking*	6.98[b]	7.28[ab]	7.45[a]	7.50[a]
Purchase intention**	4.46[a]	4.26[a]	4.21[a]	4.16[a]
Weak fish *nuggets* aroma	90[a]	21[a]	8[a]	12[a]
Strong fish *nuggets* aroma	5[a]	1[a]	6[a]	5[a]
Dry texture	**18**	**9**	**9**	**13**
Acid aftertaste	3	2	0	1
Crumbly	1	0	3	5
Homogeneous mass	23	22	11	13
Brittle mass	**2**	**1**	**5**	**6**
Light golden color	**21**	**9**	**8**	**7**
Dark golden color	**5**	**8**	**10**	**13**
Salty taste	12	8	9	9
Weak fish *nuggets* flavor	**9**	**10**	**6**	**3**
Strong fish *nuggets* flavor	**19**	**8**	**11**	**16**
Bitter aftertaste	2	0	2	3
Metallic flavor	0	0	0	1
Juicy	10	5	6	7
Crunchy	**6**	**5**	**20**	**17**
Gummy	2	3	1	0
Soft	**20**	**17**	**7**	**10**

Terms in bold indicates differences ($P < 0.05$) among *nuggets* formulations. ¥Control (100% of wheat flour), T1 (90% of wheat flour+ 10% of fish flour), T2 (75% of wheat flour + 25% of fish flour), and T3 (60% of wheat flour+ 40% of fish flour). *Evaluated in a 9-point category scale (1 = dislike extremely to 9 = like extremely). **Evaluated in a 7-point category scale (1 = would always buy to 7 = would never buy).

Internal preference mapping

T3 and T2 were preferred by the majority of the participants, followed by T1 and control (Figure 1), corroborating with our results of overall liking. In agreement with our findings, Bastos et al. (2014) found high preference for breads manufactured with 10% and 20% of fish flour. The same pattern was reported by Goes et al. (2016) in pasta containing 20% of fish flour. In contrast, other studies observed a lesser preference in products with fish flour inclusion such as breads (Chambó et al., 2017) and noodles (Chin & Yang, 2012). The successful application of fish flour in food products without negative changes in sensory properties depends mainly on fish species, type of product, processing, and wheat/fish flour ratios (Feltes et al., 2010; Monteiro et al., 2016; Souza et al., 2017). Our results demonstrate that replacement of 25% (T2) and 40% (T3) of wheat flour coating with fish flour increased overall liking and preference of fish *nuggets*.

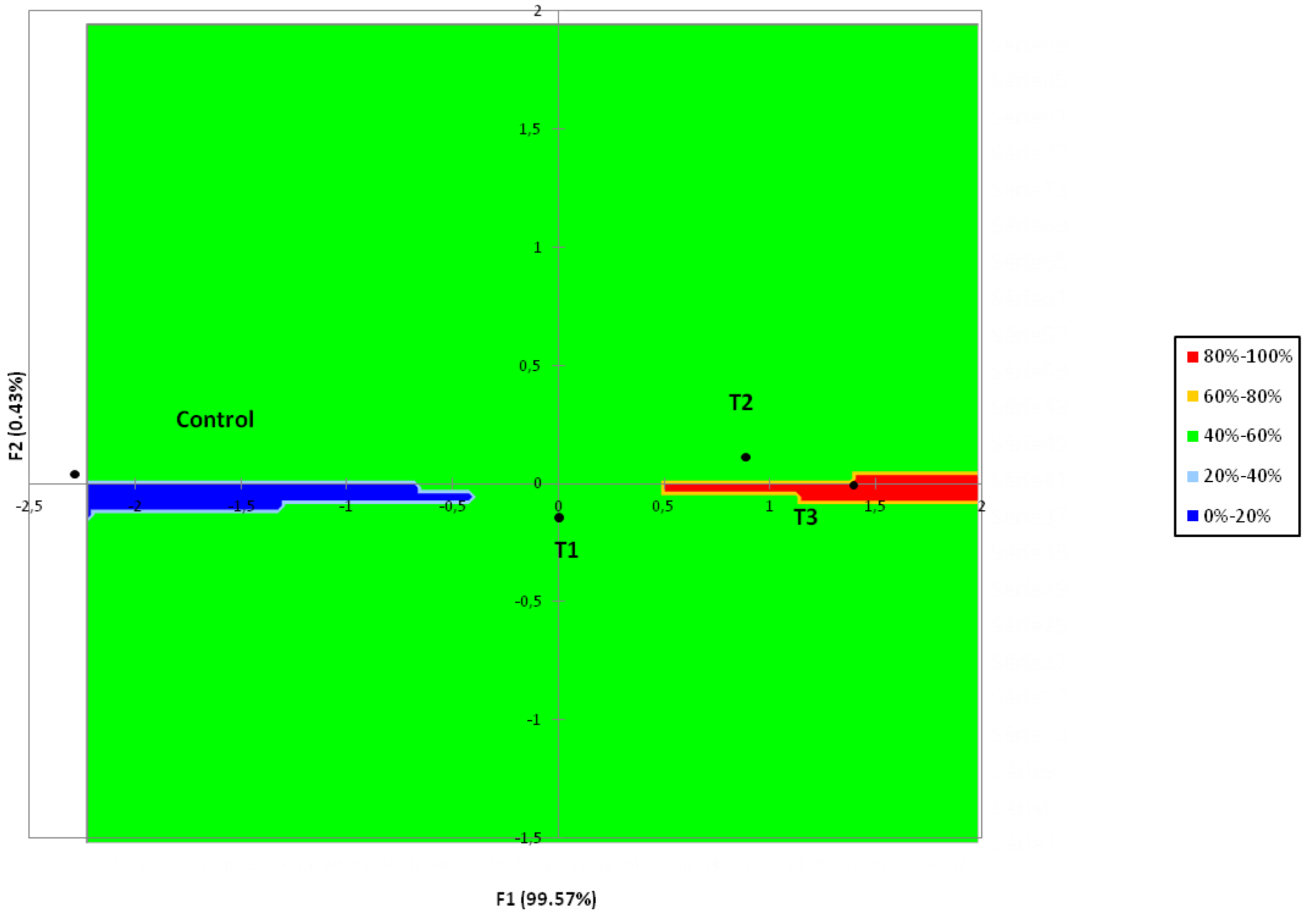

Figure 3. Internal preference mapping – color counter plot of the average overall liking scores by consumers.Control (100% of wheat flour), T1 (90% of wheat flour + 10% of fish flour), T2 (75% of wheat flour + 25% of fish flour), and T3 (60% of wheat flour+ 40% of fish flour).

Check-all-that-apply (CATA)

The two dimensions (Dim1: 61.70% and Dim 2: 29.06%) of the Correspondence Analysis (CA) explained 90.76% of the data variance (Figure 2). Control formulation was characterized by strong fish *nuggets* aroma, and dry texture, while T1 was perceived by consumers as having gummy, soft and weak fish *nuggets* flavor. T2 was mainly characterized by crunchy, brittle mass and bitter aftertaste. T3 was perceived by consumers as having weak fish *nuggets* aroma, strong fish *nuggets* flavor, dark golden color, metallic flavor, and brittle mass. The inclusion of fish flour affected 8 sensory attributes: dry texture, brittle mass, light golden color, dark golden color, weak fish *nuggets* flavor, strong fish *nuggets* flavor, crunchy and soft (Table 6). Based on frequency (%) of the CATA terms (Table 6) and CA (Figure 2), the replacement of 25% and 40% of wheat flour coating by fish flour decreased the dry texture and soft, strong fish *nuggets* aroma, while increased brittle mass, crunchy, dark golden color, and strong fish *nuggets* flavor. Although bitter aftertaste and metallic flavor has been related to T2 and T3 (Figure 2), respectively, both sensory attributes were not significant for differentiate the *nuggets* formulations (Table 6). To the best of our knowledge, there are no studies regarding sensory characterization of fish *nuggets* enriched with fish flour coating by CATA analysis. Nevertheless, sensory changes in color, flavor and texture have been previously reported in products with addition of fish flour (Sirichokworrakit, 2014; Chambó et al., 2017).

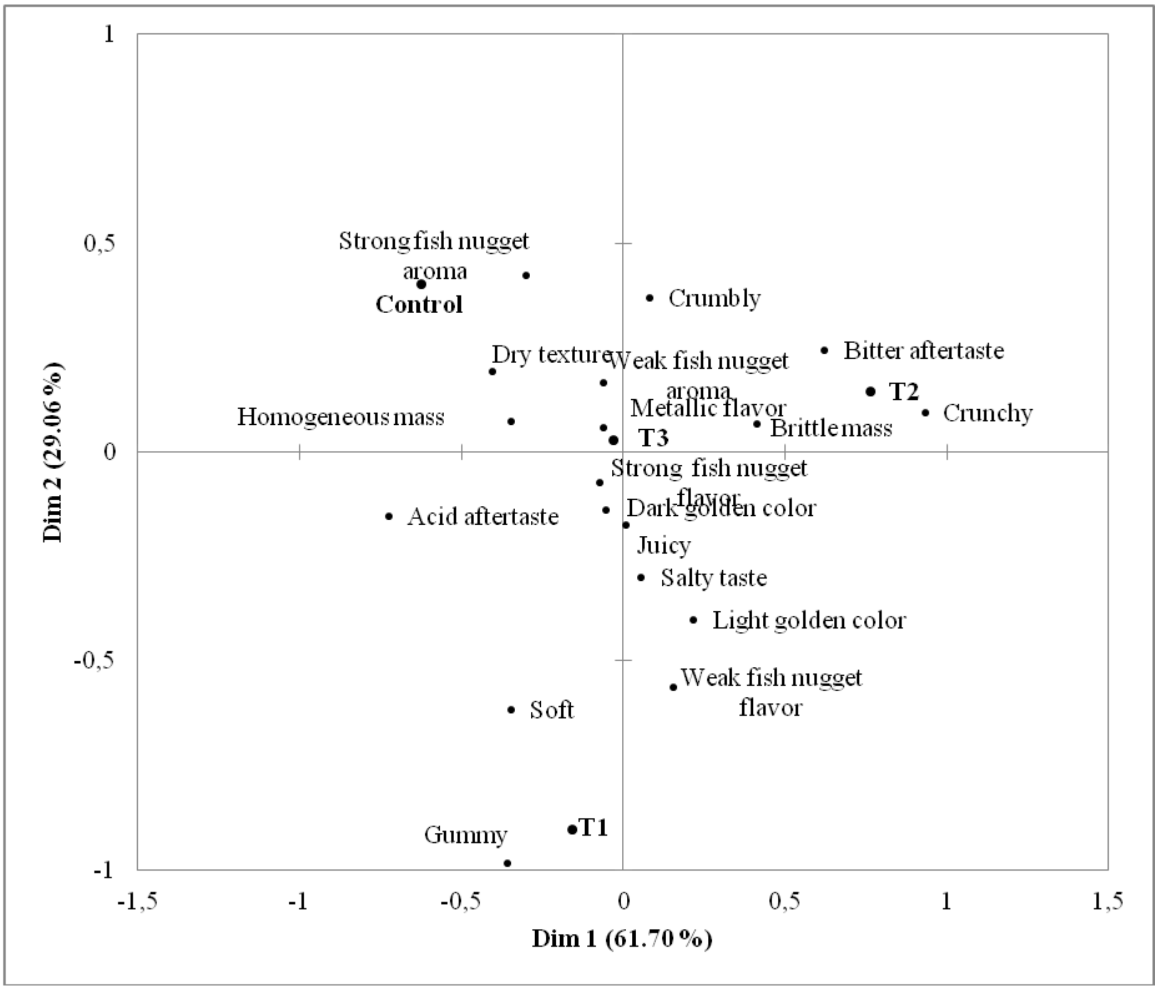

Figure 4. Representation of the fried fish nugget formulations and terms in the first (Dim 1) and second (Dim 2) dimension of the Correspondence Analysis. Control (100% of wheat flour), T1 (90% of wheat flour + 10% of fish flour), T2 (75% of flour + 25% of fish flour), and T3 (60% of wheat flour+ 40% of fish flour).

External preference mapping

T3 and T2 had the highest values for brittle mass and crunchy, while the control showed the greatest softness (Figure 3). The results of brittle mass can be explained by the difference in the particle size between wheat and fish flours. Overall, fish flour (500-1000 μm) has larger particle size than refined wheat flour (140-390 μm) (Gaines, 1985; Monteiro et al., 2014). According to Langley & Green (1989), larger particles result in product more brittle. Flour coating with large particles result in a greater oil absorption by the fried product, which interferes in the starch gelatinization preventing the formation of structural fibrils of the mass leading to weaker mass (Camire et al., 1990; Soto-Jover et al., 2016). Crunchy is one of the main characteristic for acceptance of fried products (Albert et al., 2009; Chen et al., 2009). In addition, this attribute is positively correlated with the hardness (Chen et al., 2009). In our study, the fried *nuggets* formulations containing high level of fish flour coating (T2 and T3) were harder by instrumental texture analysis. The increased hardness by fish flour addition may be attributed to insoluble network formed by denatured proteins (Martens et al., 1982 Desai et al., 2018), which can explain the highest crunchy in T2 and T3 (Chen et al, 2009). Similarly, Chen et al. (2009) also verified an increase in the hardness and crunchy when protein was added to flour coating of fish *nuggets*.

The strong fish *nuggets* flavor in T3 and T2 (Figure 3) can be explained by the higher concentration of fish flour in the formulations (Monteiro et al., 2014; Goes et al., 2016; Desai et al. al., 2018). In addition, the protein denaturation that occurs during heating process may favor the fish flavor (Bochi et al., 2008). In agreement with our findings, Lelana et al. (2003) and Widodo et al. (2015) reported that biscuits containing fish flour showed higher fish flavor than their control counterparts. Moreover, the inclusion of fish flour increased the perception of dark golden color in T2 and T3 by the consumers (Figure 3), corroborating with our results of *a** and *b** values (Table 4). Fish flour has a typical darker color compared to refined white wheat flour (Oliveira et al., 2015; Mellado-Ortega & Hornero Méndez, 2016). In addition, Maillard reaction occur during the heating process through reactions between amine groups of proteins and reducing ends of polysaccharides reflecting in increased *a** and *b** values and browning of the product (Dickson, 2008; Monteiro et al., 2016). Previous studies also reported an increase in perception of darker color by consumers when fish flour was added to heated products (Lelana et al., 2003; Widodo et al., 2015; Monteiro et al., 2016; Goes et al., 2016). In general, fried products have golden coloration, and it is one of the main attributes that affect the consumer acceptance (Chen et al. 2009). Our study demonstrates that consumers preferred fish *nuggets* with dark golden color instead light golden color.

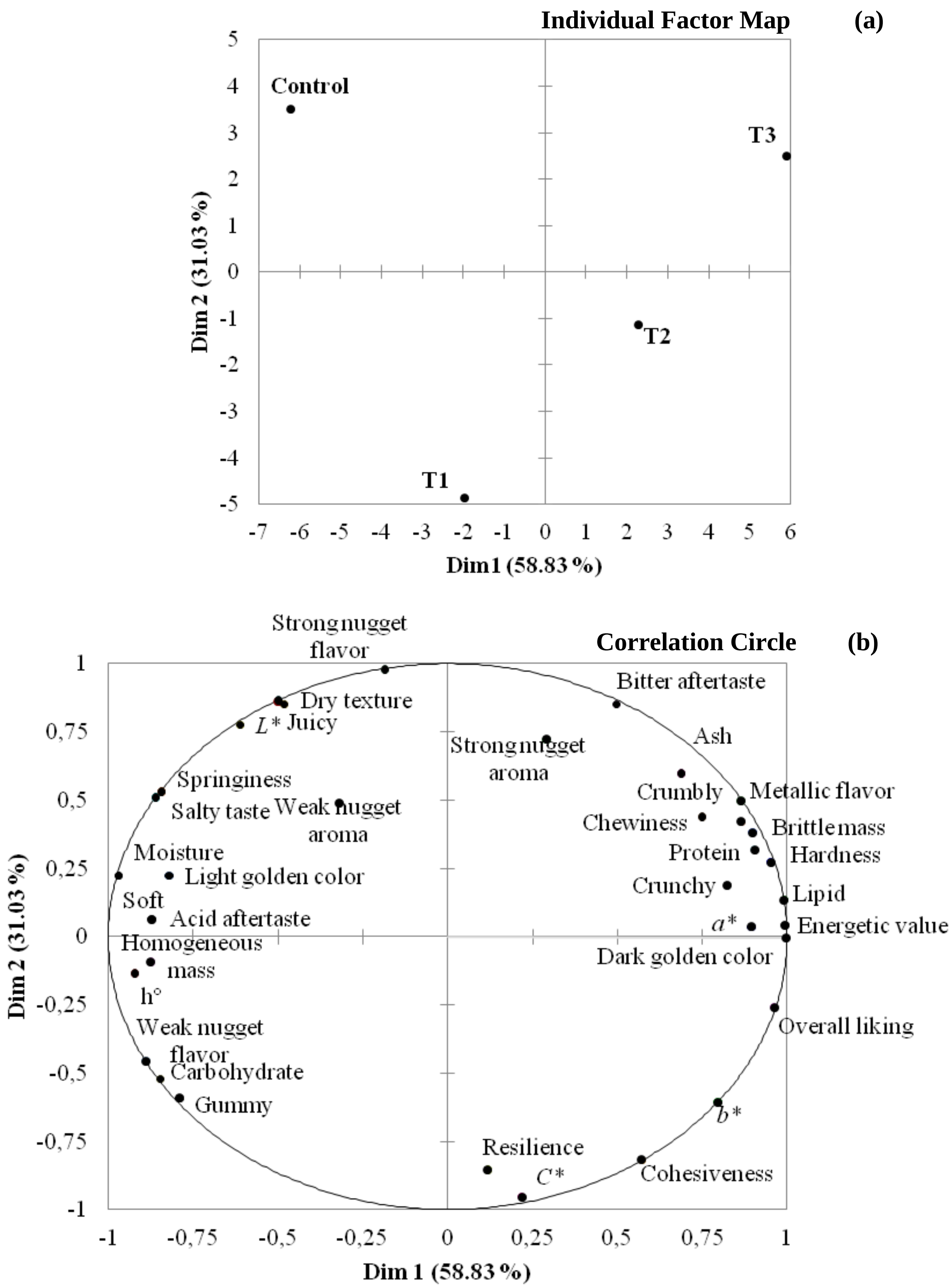

Figure 5. Representation of the fried fish nugget formulations (a) and their physicochemical, instrumental and sensory characteristics (b) provided by Multifactorial Analysis (MFA). Control (100% of wheat flour), T1 (90% of wheat flour + 10% of fish flour), T2 (75% of flour + 25% of fish flour), and T3 (60% of wheat flour+ 40% of fish flour).

Consumer interest

The majority of consumers (98.67%) showed interest in eating *nuggets* with higher protein and mineral contents. Currently, global demand for fishery products has increased due to the high nutritional value of this food matrix (Thorkelsson et al., 2009; Shaviklo, 2013). In addition, today's consumers are also looking for ready-to-cook and/or ready-to-eat products, with easy preparation and longer shelf-life (Bordigno et al., 2010; Almeida et al., 2015).

Conclusions

The partial replacement of wheat flour coating by fish flour improved the nutritional value and promoted a darkening of both pre-fried and fried fish *nuggets*. The changes in texture by substitution of wheat flour coating by FF were variable depending on time/temperature combinations. The color, flavor and texture attributes were determinants for consumers differentiate the enriched and non-enriched fish *nuggets* formulations. FF inclusion enhanced perception of dark golden color, fish flavor, and crunchy, which had positive impact on overall liking and preference. Considering the nutritional and sensory benefits, the use of 40% FF in partial substitution to wheat flour in the coating of fish *nuggets* is an attractive alternative for health food market in order to satisfy consumer and industry requirements.

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6. Considerações Finais

- A produção da farinha de peixe com a polpa de pescado retirada da carcaça de peixe se mostrou uma técnica viável;
- A substituição parcial da farinha de trigo pela farinha de peixe na mistura de empanar aumentou significativamente os valores de proteínas, cinzas e lipídios e reduziu os valores de carboidratos nos *nuggets*;
- A inclusão da farinha de peixe na massa de empanar dos *nuggets* provocou um escurecimento das amostras e um aumento na dureza dos *nuggets* fritos;
- A substituição parcial da farinha de trigo por farinha de peixe provocou mudanças sensórias no sabor, cor e textura que foram percebidas pelos julgadores;
- Apesar das mudanças sensoriais, os produtos com a farinha de peixe apresentaram aceitação positiva em relação ao controle;
- Nossos resultados confirmam a hipótese deste trabalho de que maiores percentagens de farinha do *P. arenatus* na elaboração de *nuggets* favorecerão um alimento mais rico nutricionalmente e com sabor mais marcante, quando comparado aos *nuggets* com farinha de trigo;
- O produto com 40% de farinha de peixe foi a formulação que apresentou os maiores valores nutricionais e sensoriais, demonstrando ter potencial para atender ao mercado de produtos rápidos para preparo e nutritivos, além de ser uma alternativa para as indústrias para aumentar o rendimento da matéria prima e elaboração de novos produtos.

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Anexo 1 - Questionário de perfil do avaliador e avaliação sensorial

Sexo:

( ) Feminino ( ) Masculino

Idade:

( ) 18-25 anos ( ) 26-35 ( ) 36-45 ( ) 46-55 ( ) 56-65 ( ) > 66 anos

Escolaridade:

( ) Fundamental incompleto

( ) Fundamental completo

( ) Médio incompleto

( ) Médio completo

( ) Superior incompleto

( ) Superior completo

( ) Pós-graduação

Renda familiar mensal (SM: Salário Mínimo 2017 = R$ 937,00):

( ) 1 a 5 SM

( ) > 5 a 10 SM

( ) > 10 a 20 SM

( ) > 20 a 30 SM

( ) > 30 SM

Com que frequência você consume nuggets?

( ) Nunca

( ) Raramente

( ) Frequentemente

( ) Diariamente

( ) Mais que uma vez ao dia

Você estaria interessado em consumir um nugget com maior teor de proteína e minerais como estes servidos anteriormente?

( ) Sim ( ) Não

Amostra: 215

Você está recebendo uma amostra de nugget. Por favor, observe/prove a amostra e marque o quanto você gostou na escala abaixo.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Desgostei extremamente	Desgostei muito	Desgostei moderadamente	Desgostei ligeiramente	Não gostei e nem desgostei	Gostei ligeiramente	Gostei moderadamente	Gostei muito	Gostei extremamente

Indique o atributo que você mais gostou ou desgostou da amostra:

Mais gostou:____

Mais desgostou____

Imagine que você comprou o produto para comê-lo ou que ele foi servido a você em sua casa. Você consumiria este produto?

(   ) Sim   (   ) Não

Por favor, avalie a amostra e utilize a escala abaixo marcando um "X" no espaço entre parênteses para indicar o quanto você estaria disposto a comprar este produto.

☐	☐	☐	☐	☐	☐	☐
Compraria sempre	Compraria muito frequentemente	Compraria frequentemente	Compraria ocasionalmente	Compraria raramente	Compraria muito raramente	Nunca compraria

Agora, marque os atributos que você considera adequados para descrever esta amostra.

Aroma característico fraco ( )	Gosto salgado ( )
Aroma característico forte ( )	Sabor característico fraco ( )
Textura seca ( )	Sabor característico forte ( )
Gosto ácido residual ( )	Gosto amargo residual ( )
Esfarelento ( )	Sabor metálico ( )
Massa homogênea ( )	Suculento ( )
Massa quebradiça ( )	Crocante ( )
Cor dourada clara ( )	Gomoso ( )
Cor dourada escura ( )	Macio ( )