millenium 69

Millenium, 2(8), 69-78.

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EFEITO DOS HIDROCOLÓIDES NO REVESTIMENTO E NAS PROPRIEDADES ORGANOLÉTICAS DO RISSOL REGENERADO EM FORNO E COMPARAÇÃO COM O PROCESSO DE FRITURA

HYDROCOLLOIDS EFFECT ON COATING BATTER AND ON ORGANOLEPTIC PROPERTIES OF RISSOL REGENERATED IN OVEN AND COMPARISON WITH DEEP-FRYING PROCESS

EFECTO DE LOS HIDROCOLOIDES EN EL REVESTIMIENTO Y EN LAS PROPIEDADES ORGANOLÉTICAS DEL RISSOL REGENERADO EN HORNO Y COMPARACIÓN CON EL PROCESO DE FRITURA

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RECEIVED: 29th May 2018
ACCEPTED: 03th January 2019

Sousa, A. P., Velho, M. V., Alves, M. & Pinheiro, R. (2019). Hydrocolloids effect on coating batter and on organoleptic properties of rissole regenerated in oven and comparison with deep-frying process. *Millenium*, 2(8), 69-78.
DOI: https://doi.org/10.29352/mill0208.06.00198

RESUMO

Introdução: A preferência dos consumidores por produtos com baixo teor de gordura continua a aumentar e há uma pressão significativa na indústria para reduzir processos de fritura.
Objetivos: Avaliar o efeito dos hidrocolóides no revestimento do *Rissol*, evitando os processos de pré-fritura ou fritura. Pretende-se também comparar as características físico-químicas do *Rissol* obtido, usando o processo de regeneração em forno e o tradicionalmente frito, e a aceitabilidade do consumidor do *Rissol* regenerado em forno.
Métodos: Hidrocolóides como carboximetilcelulose, hidroxipropilmetilcelulose, metilcelulose, gomas xantana, karaya e alfarroba, foram utilizadas sozinhas no sistema de revestimento, a uma concentração de 0.5% e 1.5%(p/p), assim como a sinergia estabelecida entre pares de gomas com concentração final de 1% (p/p). O *Rissol* foi regenerado em forno (200°C; 18 minutos). Analisou-se o efeito na cor, textura instrumental, humidade e propriedades organoléticas (análise descritiva quantitativa). O teor em proteínas, hidratos de carbono, gordura total, fibra, cloreto de sódio, humidade e a aceitabilidade do consumidor no *Rissol* com 0.5%(p/p) de carboximetilcelulose foi determinado, para comparar os processos de cozimento em forno e fritura.
Resultados: O uso de 0,5%(p/p) de hidrocolóides adicionado ao sistema de revestimento oferece melhores perspetivas para a produção de um produto sem pré-fritura. As formulações com 1,5%(p/p) apresentaram uma aparência visual pior com fissuras e grumos.
Conclusão: O uso de carboximetilcelulose no sistema de revestimento do *Rissol* pode ser uma alternativa para obter um produto com um teor de gordura reduzido e com resultados positivos de aceitação pelo consumidor (com regeneração em forno).

Palavras-chaves: Hidrocolóides; Carboximetilcelulose; solução de revestimento; conteúdo em gordura;

ABSTRACT

Introduction: Consumers' preference for lower fat products continues to increase and there is a significant pressure on industry to reduce the use of frying processes.
Objetives: Evaluate the effect of hydrocolloids on the *Rissol* coating, avoiding the pre-frying or frying processes. It's also intended to compare physicochemical characteristics of the *Rissol* obtained, using oven regeneration process and traditional deep-frying, and consumer's acceptability of oven regenerated *Rissol*.
Methods: Hydrocolloids such as carboxymethylcellulose, hydroxypropylmethylcellulose, methylcellulose, xanthan, karaya and locust bean gums, were used alone in the coating system at concentrations of 0.5% and 1.5%(w/w), as well as the synergies established between pairs of gums to a final concentration of 1%(w/w). Rissol was regenerated in the oven (200°C, 18 minutes) and instrumental texture, colour, moisture and organoleptic properties (quantitative descriptive analysis) were measured.
The contents in protein, carbohydrates, total fat, fibre, sodium chloride and moisture and consumer's acceptability in *Rissol* with 0.5%(w/w) of carboxymethylcellulose were determined, to compare deep-frying and oven cooking processes.
Results: The addition of 0.5%(w/w) of any of hydrocolloids studied to the coating system offers better prospects to produce an oven product without pre-frying. The formulations with 1.5%(w/w) of hydrocolloid showed a poorer appearance with cracks and lumps.
Conclusion: The use of carboxymethylcellulose in coating batter could be an alternative to obtain a product with reduced total fat and with positive consumer acceptability results (with oven regeneration).

Keywords: Hydrocolloids; Carboxymethylcellulose; Batters; fat content

RESUMEN

Introducción: La preferencia de los consumidores por productos con bajo contenido de grasa sigue aumentando y hay una presión significativa en la industria para reducir el uso de procesos de fritura.
Objetivos: Evaluar el efecto de los hidrocoloides en el revestimiento del *Rissol*, evitando los procesos de pre-fritura o fritura. También se pretende comparar las características fisicoquímicas del *Rissol* obtenido, utilizando el proceso de regeneración en horno y el tradicionalmente freído y la aceptabilidad del consumidor del *Rissol* regenerado en horno.
Métodos: Hidrocoloides tales como carboximetilcelulosa, hidroxipropilmetilcelulosa, metilcelulosa, gomas xantana, karaya y algarroba, se usaron solos en el sistema de revestimiento a concentraciones de 0.5% y 1.5% (p/p), así como las sinergias establecidas entre pares de gomas a una concentración final de 1%(p/p). El *Rissol* fue regenerado en horno (200°C, 18 minutos). Se analizó el efecto en el color, textura instrumental, humedad y propiedades organoléticas (análisis descriptivo cuantitativo).
El contenido en proteínas, hidratos de carbono, grasa total, fibra, cloruro de sodio, humedad y la aceptabilidad del consumidor en el *Rissol* con 0.5% (p/p) de carboximetilcelulosa fue determinado, para comparar los procesos de cocción en horno y fritura.

Resultados: El uso del 0,5% (p/p) de hidrocoloide agregado al sistema de recubrimiento ofrece mejores perspectivas para la producción de un producto sin pre-fritura. Las formulaciones con 1,5% (p/p) presentaron una apariencia visual peor (fisuras y grumos).
Conclusións: El uso de carboximetilcelulosa en el sistema de revestimiento del *Rissol* puede ser una alternativa para obtener un producto con un contenido de grasa total reducido y con resultados positivos de aceptación por el consumidor (con regeneración del horno).

Palabras Clave: hidrocoloides; carboximetilcelulosa; solución revestimiento; contenido en grasa;

INTRODUCTION

The high consumption of lipids has been related to obesity and other health problems, such as cardiac diseases (Gadiraju et al., 2015). World Health Organization (WHO) encouraged the nutritional reformulation of food products through an articulated action with Food Industry, especially in products with high quantities of sugar, salt and fat (World Health Organization, 2015). In fried foods, the application of batter and breading provides many opportunities to develop flavours and textures (Xue & Ngadi, 2007; Brannan et al., 2014). Batter is a liquid dough containing essentially flour and water, but may contain other ingredients, for example, egg, starch, salt, and others (Fiszman & Salvador, 2003; Yilmaz et al., 2017). The main purpose of batter is to create a layer to which the breading adheres completely. In addition to this function, batter acts as a barrier to prevent moisture loss, thus ensuring an end product with a smooth and juicy inside, and crispy outside (Albert, et al., 2009). Manipulating the coating (batter and breading system) of some foods can be a good method to reduce fat absorption during the frying process, while promoting the retention of water inside (Singthong & Thongkaew, 2009). Polysaccharides, have been shown to be effective in reducing the amount of absorbed oil (Fiszman & Salvador, 2003; Brannan et al., 2014). Hydrocolloids have functions as thickeners, gelling agents, emulsifiers, stabilizers, fat replacers, clarifying agents, flocculating agents, clouding and whipping agents. In addition, they have applications in the areas of edible films and crystallization inhibition (Li & Nie, 2016). The use of hydrocolloids in batters, with the formation of a thin and invisible film, besides reducing oil absorption, it also contributes to the improvement of the viscosity, adhesiveness, mechanical resistance of the crust and pickup control. It also helps in the control and stability of the freezing/defrosting processes and maintains crispness of the fried breaded foods (Fiszman & Salvador, 2003; Varela & Fiszman, 2011). Many hydrocolloids are highly hydrophilic, requiring the adjustment of the solids/water ratio of the formulation, so that the hydrocolloid efficiency is not affected due to competition for the available water (Meyers & Grazela, 2011). Among the hydrocolloids, hydrophilic polymers (e.g., alginates, carrageenans, carboxymethylcelluloses, pectins, xanthan gum) are widely used as film formers because they preserve the texture, flavour, and shelf life of foods. Among the wide variety of gums used as fat barriers, the most studied have been cellulose esters, methylcellulose (MC) and hydroxypropylmethylcellulose (HPMC) (Varela & Fiszman, 2011), which exhibit unique properties of reversible thermal gelation (Xue & Ngadi, 2007; Varela & Fiszman, 2011). When MC or HPMC is added to the coating solution, it gels immediately when the product comes into contact with the hot oil. This property, coupled with its high water retention capacity, allows these gums to protect food from water loss from the substrate and therefore prevent oil absorption during the frying process (Meyers & Grazela, 2011). One factor that has been associated with barrier efficacy is the MC concentration in the coating solution. Sanz et al. (2004a) found that the increase in MC concentration from 1 to 2% (w/w) leads to a lower oil absorption and a greater reduction of moisture on the crust of the coated squid rings, both in pre-frying and in final frying following freezing. The same authors found that another factor that has been related to barrier efficiency is the temperature of the solution at the time of coating application. The application of MC is its use in industrial process of frozen food, which uses its thermogelling properties to eliminate the pre-frying phase (Sanz et al., 2004b). Carboxymethylcellulose (CMC) is another hydrocolloid, derived from cellulose, which has been extensively studied (Varela & Fiszman, 2011). However, it has been reported to be less efficient than MC and HPMC (Varela & Fiszman, 2011). Ajo (2017) investigated the effects of using carrageenan and xanthan thin coating films to reduce oil absorption in fried potato chip-based pellets and concluded that these hydrocolloids significantly reduced oil absorption across all concentrations, and the most effective level of fat reduction was found using 4% (w/w) carrageenan and 0.3% (w/w) xanthan coatings.
Regeneration in the oven at higher temperatures results in better evaluations regarding characteristics such as 'roast', 'roasted' and 'bitter', which can be related to the fact that high temperatures favour the Maillard reactions without, however, implying a decrease in the development of the characteristic flavour (Byrne, Bredie, Mottram, & Martens, 2002).
Rissol is a traditionally consumed food product in Portugal, whose wrapping dough is pre-cooked, stuffed with meat, fish or vegetables and coated with egg (batter) and breadcrumb (breading) before being fried.
The aim of this study was to evaluate the effect of the hydrocolloids on the *Rissol* coating, avoiding the processes of pre-frying or frying. The effect of different hydrocolloids (Carboxymethylcellulose, methylcellulose, hydroxypropylmethylcellulose, xanthan

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gum, karaya gum and locust bean gum) incorporated in the coating solutions on colour, instrumental texture, moisture and organoleptic properties were analysed. Comparisons of physicochemical characteristics and energetic values of the *Rissol* with CMC in the batter solution, was also studied, using the oven regeneration method and the traditional deep-frying, as well as consumer's acceptability of oven regenerated *Rissol* were also carried out.

1. METHODS

1.1 Sample

1.1.1 Effect of different hydrocolloids in batter solution

Batter solution: xanthan gum (XA), locust bean gum (AL), karaya gum (KA), carboxymethylcellulose (CMC) (Formulab, Ltd), hydroxypropylmethylcellulose (HPMC) (Methocel K4M - Dow Chemical Company) and methylcellulose (MC) (Capri, Ltd.), at concentrations of 0.5% and 1.5% (w/w), were used for each hydrocolloid. The effect of the combination of different hydrocolloid doubles was also analysed at a concentration of 0.5:0.5 - 1% (w/w) - MC + KA, MC + AL, MC + XA, CMC + KA, CMC + AL, CMC + XA. The solutions were prepared by diluting the hydrocolloid in distilled water, and letting it stand for 24 hours before use.
Preparation of the samples: A meat *Rissol*, supplied by a local company, was used as sample. *Rissol* formulation was: 65% dough (60% of wheat flour; 39% of water and 1% of salt) and 35% meat mixture (40% of water, 35% of pork meat and 25% of wheat flour). In the coating system, the sample was dipped (± 20 °C) into the batter liquid solution (hydrocolloid solution). The batter was drained from the sample during 10 seconds. After this, the breading step with breadcrumb was followed. The samples were frozen (-18 ºC) for 1 hour in a quick freezer equipment (Mercatus, Italy) and stored at the same temperature.
Samples were regenerated in a conventional electric oven (FE 2/3, Italy) at 200 °C ± 5 °C for 18 to 20 minutes.

1.1.2 Comparison between two cooking methods

Samples followed the same preparation method described above. A batter solution containing 0.5% of CMC was used in the coating system. After being immersed in the solution, the *Rissol* was breadcrumbs. Subsequently, *Rissol* was regenerated in the oven, at 200 °C for 18 to 20 minutes or deep-fried with sunflower oil at 180 °C for 12 minutes.

1.2 Procedures

1.2.1 Effect of different hydrocolloids in batter solution

A texture profile analysis test (TPA) using a texture analyser (TA.XT2i) equipped with a cylindrical probe (P/4) was used with a force and speed of 0.049 N and 5 mm/s, respectively. A colour analyser (Minolta CR-300), using CIE L* a* b* colour space, recording the values of brightness L*, chromaticity a* (red-green) and b* (yellow-blue). Moisture was determined according to ISO 1442:1997, by gravimetric method, by means of the evaluation of mass loss up to constant weight in an oven (Heraeus, Germany) regulated at 103 ± 2 °C. Five replicates were performed for each sample (T = 20 °C) for texture and six for colour and moisture. A quantitative descriptive analysis (QDA) was performed by a sensory trained panel with 14 elements, involving previous sessions for main descriptors definition, their scale limits as well as verbal anchors, using the very same type of commercial *Rissol* (ISO 8587,2006). The samples were evaluated for general appearance, smell, texture appreciated with cutlery and texture in mouth, with a 9 – point scale anchored at the ends with 1 – little / absent and 9 – very / intense (Stone & Sidel, 2004)

1.2.2 Comparison between two cooking methods

The protein content was determined by the Kjeldahl method, described by ISO 937:1978. A digestion unit (Buchi, Switzerland) and a Vapodest distillation unit (Gerhardt, Germany) were used. The conversion of the total nitrogen content to crude protein content was obtained by the standard conversion factor (6.25). The fat content was determined by the Soxhlet method, described by ISO 1443:1973. The carbohydrates were determined by the 3,5-dinitrosalicylic acid colorimetric method (DNS) (James, 1995). The absorbance were measured on the spectrophotometer (Varian Cary 50, California) at 540 nm. The dietary fibre was determined by the Ceramic Fibre Filter Method, described by AOAC 962.09:1995. The sodium chloride content was determined by Volhard method, described by ISO 1841-1:1996. The moisture was determined following the method described above ISO 1442:1997. All analysis were performed in triplicate. The energy value was calculated according to conversion factors, according to Regulation (EU) 1169:2011.

1.2.3 Consumer acceptance test

The consumers' acceptance was evaluated in a global way, using *Rissoles* with 0.5% CMC (w/w) in the coating system and regenerated in the oven. Consumers (N=73) were originally from the North region of Portugal and select with ages older than 18 years old. A survey was used and consumers would have to identify age and sex. A 5-point hedonic scale ranking from 1= dislike very much to 5= like very much was used to evaluate acceptance (Meilgaard, Civille, & Carr, 1999)

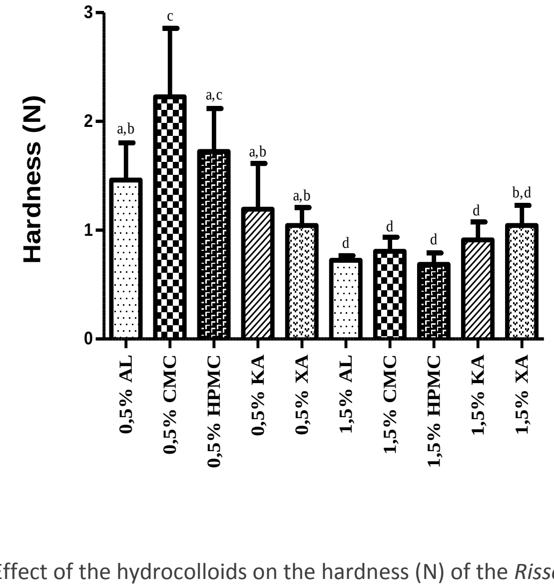
1.3 Statistical analysis

The effect of different hydrocolloids in batter solution (except sensory analysis) were analysed using analysis of variance (*one-way* ANOVA), followed by Tukey's HSD test. Sensory analysis was evaluated by principal component analysis (PCA) with predictive biplots (Alves, 2012). The comparison between two cooking methods was analysed using Student's t-test. Statistical significance was set at *p* values less than 0.05. All analyses were performed with the R Project for Statistical Computing program (www.r-project.org).

2. RESULTS AND DISCUSSION

2.1 Effect of different hydrocolloids in batter solution

Regarding texture results, it was observed that samples with a concentration of 0.5% (w/w) present higher hardness values than those with 1.5% (w/w) ($p<0.05$) regardless of the type of hydrocolloid used (Figure 1- left). This behaviour may be due to a greater dehydration of the *Rissol* during its regeneration in the oven by the lower concentration of hydrocolloid, 0.5%, making its hardness higher than 1.5% (w/w) of hydrocolloid. Samples with a concentration of 0.5% (w/w) of CMC and HPMC showed the highest hardness values. On the contrary, samples with 1.5% (w/w) of LA revealed the lowest hardness values. Samples with 1.5% (w/w) of hydrocolloids showed not differences in hardness results ($p<0.05$). It was also observed that the XA gum shows similar values for the hardness for two concentrations ($p<0.05$). On the contrary, Lazaridou, Duta, Papageorgiou, Belc, & Biliadereis (2007) found in a rheology study on gluten-free bread that XA gum, in concentrations of 1 and 2%, enhances the effect of bread hardness and elasticity . Guarda, Rosell, Benedito, & Galotto (2004), found that a concentration of 0.1% (w/w) of this hydrocolloid increased the hardness in the bread crumb, maintaining that effect constant at higher concentrations. However, it must be pointed out that the food matrix analysed was different from *Rissol*. The results obtained for the elasticity (Figure 2-left) indicated that, in general, the elasticity is higher for samples with 0.5% (w/w) of hydrocolloid, the highest values were with concentrations of 0.5% (w/w) (CMC and AL). The synergies between the hydrocolloid pairs (Figure 1, right), both in the hardness values and in the elasticity values (Figure 2, right) did not revealed any tendency, although there were significant differences between the samples ($p<0.05$).



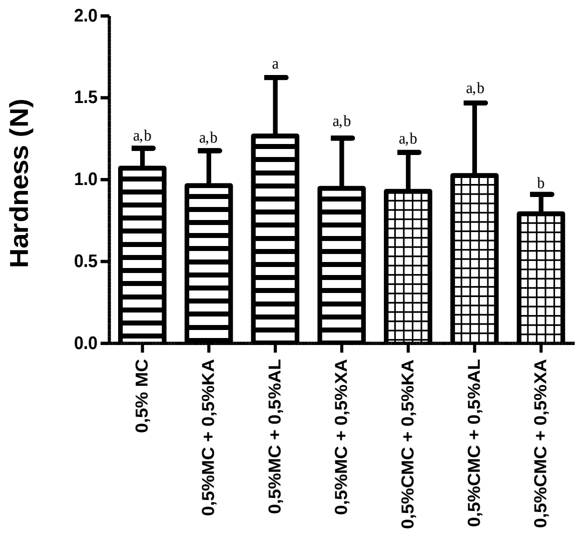


Figure 1 – Effect of the hydrocolloids on the hardness (N) of the *Rissol*, in concentrations (0.5% and 1.5%) (on the left), and in different pairs of hydrocolloids (with the exception of 0.5% MC) (right). Mean values ± standard deviation of five replicates for each sample; values with the same letter are not significantly different ($p<0.05$)

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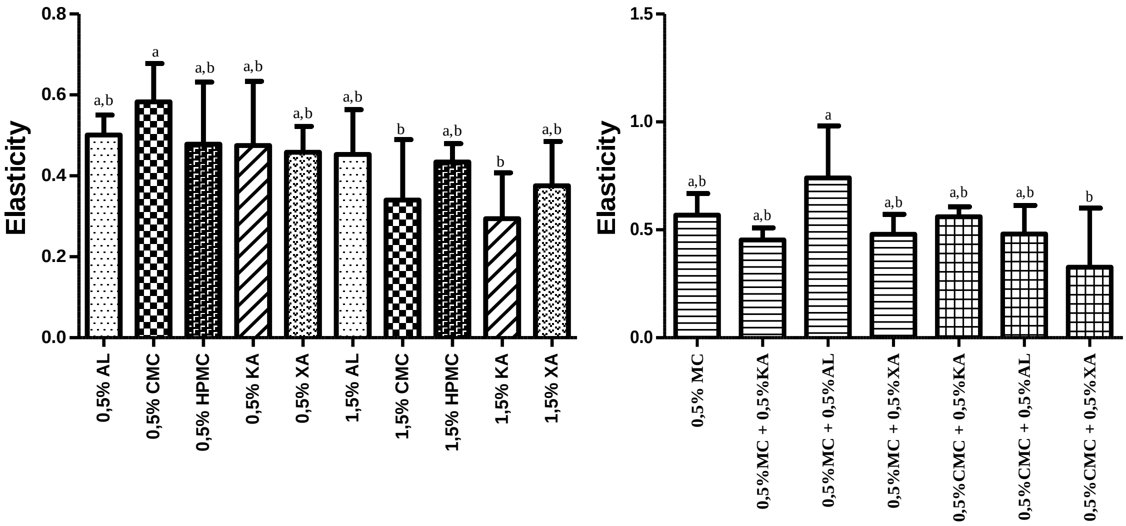

Figure 2 - Effect of the hydrocolloids on the elasticity of the *Rissol*, in concentrations (0.5% and 1.5%) (on the left), and in different pairs of hydrocolloids (with the exception of 0.5% MC) (right). Mean values ± standard deviation of 5 replicates for each sample; values with the same letter are not significantly different (p<0.05).

Colour results showed that there were significant differences between the samples with different hydrocolloids *(p*<0.05) (Table 1) (L*, a*, b*). L* values obtained were between 54.29 (± 3.29) and 62.85 (± 1.15). Samples with 0.5% (w/w) of CMC and 0.5% (w/w) of AL presented the highest values (62.85 and 61.15, respectively) and 0.5% (w/w) of HPMC and 1.5% (w/w) of KA presented the lowest values of all experiments (54.92 and 54.29, respectively). The higher L* values, the lighter are the samples, on the contrary, the lower L* values, the darker are the samples. Regarding other colour parameters, greenness (a*) and yellowness (b*), significant differences between the samples were also found (p<0.05). a* values obtained ranged from 9.23 (± 0.55) to 12.84 (± 0.18). Samples with 0.5% (w/w) of HPMC and 0.5% (w/w) of KA presented the highest values (12.84 and 12.67, respectively) and 0.5% (w/w) of AL and 0.5% (w/w) of CMC presented the lowest values of all experiments (9.23 and 10.09, respectively). b* values obtained ranged from 26.51 (± 0.84) to 31.03 (± 1.09). Samples with 0.5% (w/w) of KA and 0.5% (w/w) of HPMC presented the highest values (31.03 and 29.50, respectively) and 1.5% (w/w) of KA and 0.5% (w/w) of AL presented the lowest values of all experiments (26.51 and 26.59, respectively). The synergies of the hydrocolloid pairs (Table 2) did not show any tendency, although there were significant differences between the samples (*p*<0.05). According to Varela & Fiszman (2011), the final appearance of the breaded product depends entirely on its external characteristics, and, in this case, it is verified that the hydrocolloid does not influence the colour of the product, since the colour is very influenced by the breadcrumb.

Moisture results showed that the values varied between 38.57 (± 2.56) % and 47.22 (± 1.83) % (Table 1), for hydrocolloids 1.5% (w/w) of KA and 1.5% (w/w) of CMC, respectively, although there were no significant differences between the samples (*p*<0.05). The synergies of the hydrocolloid pairs did not show any tendency (Table 2), there were no significant differences between the samples (p<0.05). Gonçalves (2015), found that the L* values decreased significantly with the increase of the regeneration time of commercial chicken nuggets.

Table 1 - Effect of the hydrocolloids on the batter in the parameters L*, a*, b* of the colour, and moisture (%), in concentrations (0.5% and 1.5%). Mean values ± standard deviation of 6 replicates for colour and 3 replicates for moisture; Values followed by the same letter in the same column are not significantly different (p<0.05)

Formulations	Colour			Moisture (%)
	*L**	*a**	*b**	
0.5% AL	61.15 (± 3.01)a,b,f	9.23 (± 0.55)a	26.59 (± 0.96)a,b	42.35 (± 3.76)a
0.5% CMC	62.85 (± 1.15)a,g	10.09 (± 0.21)a,c	27.67 (± 0.46)b,f	43.85 (± 2.08)a
0.5% HPMC	54.92 (± 0.85)cd	12.84 (± 0.18)b	29.50 (± 0.50)c,d	42.84 (± 5.46)a
0.5% KA	57.62 (± 1.60)b,d,f	12.67 (± 0.58)b,d	31.03 (± 1.09)a,d	41.98 (± 2.40)a
0.5% XA	58.41 (± 3.54)a,b,c,d,f	10.62 (± 1.93)a,c	28.13 (± 1.31)a,b,c	45.99 (± 3.05)a
1.5% AL	58.33 (± 2.30)b,c,d,f	11.27 (± 1.00)b,c	28.39 (± 1.10)a,c,e	45.30 (± 1.80)a
1.5% CMC	58.58 (± 2.06)a,b,c,d,f	11.69 (± 0.81)b,c	28.81 (± 1.46)a,c,e	47.22 (± 1.83)a
1.5% HPMC	55.65 (± 0.95)d,e	10.95 (± 0.88)c	27.60 (± 1.67)e,f	45.21 (± 0.96)a
1.5% KA	54.29 (± 3.29)d	11.08 (± 0.50)c,d	26.51 (± 0.84)c,e	38.57 (± 2.56)a
1.5% XA	59.66 (± 2.74)e,f,g	10.98 (± 0.52)c	28.11 (± 1.36)a,b,d,f	44.45 (± 2.82)a

Table 2 - Effect of the hydrocolloids on the batter in the parameters L*, a*, b* of the colour, and moisture (%) in different pairs of hydrocolloids (with the exception of 0.5% MC). Mean values ± standard deviation of 6 replicates for colour and 3 replicates for moisture; Values followed by the same letter in the same column are not significantly different (p<0.05)

Formulations	Colour			Moisture (%)
	*L**	*a**	*b**	
0.5% MC	60.86 (± 1.46)a	10.96 (± 0.65)a	28.96 (± 0.76)a	48.68 (± 1.60)a
0.5% MC + 0.5% KA	59.97 (± 0.73)a,c	11.28 (± 0.70)a	28.99 (± 0.92)a	44.01 (± 2.39)a
0.5% MC + 0.5% AL	55.77 (± 1.64)b	9.75 (± 0.29)b	24.96 (± 0.99)b	46.11 (± 1.00)a
0.5% MC + 0.5% XA	57.66 (± 2.76)b,c	11.30 (± 1.04)a	28.70 (± 1.64)b	44.72 (± 2.73)a
0.5% CMC + 0.5% KA	61.18 (± 1.85)a	11.14 (± 0.42)a	29.20 (± 1.01)a	43.26 (± 2.90)a
0.5% CMC + 0.5% AL	59.26 (± 0.73)a,c	11.53 (± 0.20)a	29.15 (± 0.48)a	46.53 (± 2.02)a
0.5% CMC + 0.5% XA	59.48 (± 1.14)a,c	10.98 (± 0.52)a	28.35 (± 0.51)a	44.72 (± 2.73)a

Regarding the sensory analysis, as shown in Figure 3, the principal components 1 and 2 explain 54% of the total information, reflecting main observed variations among the different samples, in the attributes T1d (texture/hardness on the first bite), mc (chewing - crispness), at (aspect -characteristic texture), cc (characteristic colour) and af (visual aspect - cracks). It can then be said that the panellists have privileged the aspect (characteristic aspect, cracks, and characteristic texture) and chewiness (crispness and hardness on the 1st bite). The characteristic texture aspect correlates positively with the characteristic smell and negatively with visible cracks. It can be seen that CMC gives a more characteristic general appearance, with values between 6 - 6.5, whereas, for example, XA and KA gums give a less characteristic colour (for the 2 concentrations). *Rissol* with MC, CMC + AL, CMC + XA and CMC presented lower hardness on the first bite and less crispness; the use of HPMC demonstrated the same but less extreme behaviour. *Rissol* with MC + XA and AL1 presented a less characteristic appearance, a greater hardness, and greater crispness, whereas with AL2 they are identical with those with AL1, but with a more characteristic appearance.

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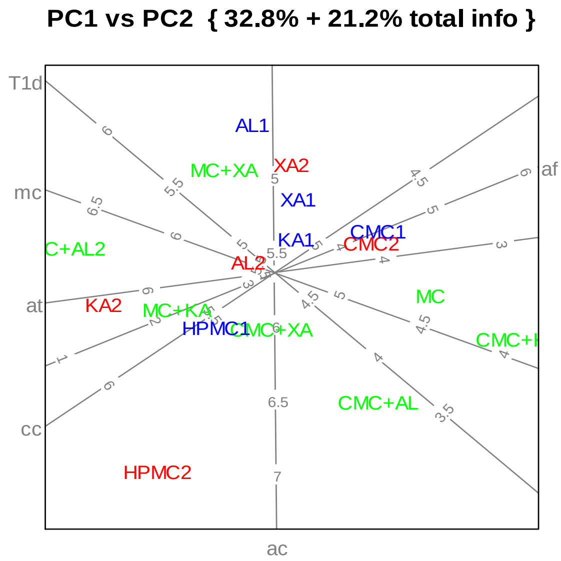

Figure 3 – Predictive PCA biplot of attributes evaluated in sensory analysis. AL1, CMC1, HPMC1, XA1 correspond to 0.5% concentrations. AL2, CMC2, HPMC2, correspond to 1.5% concentrations. The remainder correspond to the different pairs of hydrocolloids. Principal components: T1d (texture/hardness on the first bite), mc (chewing - crispness), at (visual aspect-characteristic texture), cc (characteristic color) and af (visual aspect - cracks).

Coating products are, mainly, evaluated by consumers on the basis of quality attributes including appearance, taste and smell, moisture and fat content, texture and crispness, which is perhaps one of the most important properties which determine consumer acceptance, looking for a product with a crunchy outer layer that contrasts with the soft interior (Piqueras-Fiszman, Varela, & Fiszman, 2013).

2.2 Comparison between two cooking methods: regenerate in the oven and deep-fried

The *Rissol* produced with a coating system with 0.5% (w/w) of CMC was regenerated in oven and in deep-frying. The results of protein content, carbohydrates, dietary fibre, and sodium chloride showed no significant differences between the two regenerated cooking methods ($p<0.05$) (Table 3). On the contrary, total fat content and moisture presented significant differences between the two cooking methods ($p<0.05$). The fat content of *Rissol* regenerated by the frying method has 7-fold higher, than the oven regenerated *Rissol*, 15.10 (± 0.00) % and 2.02 (± 0.00) %, respectively. The deep-fried *Rissol* presented lower moisture content, 46.10 (±0.01) %, than the oven regenerated *Rissol*, 51.84 (±0.01) %, meaning that the frying leads to higher water loss than oven process. Same results were found by Gonçalves (2015) who compared the oven regeneration with the frying process of commercial chicken nuggets. According to Varela, Salvador & Fiszman (2008), the regeneration by frying of coating products, fried and frozen leads to products with high moisture in the interior, lower moisture in the outer layer and good crispness. Results showed that oven regenerated *Rissol* contains 167 kcal per 100 g and deep-fried *Rissol* contains 273 kcal per 100 g. These results reflect a 70% decrease in Calories content that the oven regenerated *Rissol* provides, compared to the deep-fried *Rissol.*

Table 3 - Physicochemical characteristics and energetic value of oven regenerated *Rissol* without pre-frying and traditional deep-fried *Rissol*. Mean values ± standard deviation of 3 replicates; Values followed by the same letter in the same column are not significantly different (p<0.05)

	Physicochemical characteristics (%)						Energetic value (kcal)
	Total fat	Protein	Sodium chloride	Carbohydrates	Dietary fiber	Moisture	
Oven method	2.02 (±0.00)a	5.99 (±0.00)a	0.91 (±0.02)a	30.90 (±0.03)a	0.68 (±0.00)a	51.84 (±0.01)a	167
Deep frying method	15.10 (±0.00)b	5.76 (±0.00)a	1.03 (±0.09)a	28.30 (±0.03)a	0.77 (±0.00)a	46.10 (±0.01)b	273

2.2.1 Consumer acceptance test

The consumers' acceptance was evaluated in a global way, using the *Rissol* produced with a coating system with 0.5% (w/w) of CMC and regenerated in the oven. It was found that the majority of consumers scored *Rissol* as "like very much" (50.68%) and "like moderately" (46.58%) (N=73). Only two respondents revealed that "neither like or dislike" (1.37%) and "dislike moderately" (1.37%), and none revealed that "dislike very much". In the study, consumers aged between 18 and 76 participated in the study, with more than half of respondents aged 18-25 years: 18-25 years (61.64%); 26-34 years (17.81%); 35-44 years (13.70%) and 45-76 years (6.85%). Respondents were mostly women (62%).

CONCLUSIONS

Many studies have been done aiming to reduce the fat content in fried products. Developing a coating system capable of suppressing the need for frying or pre-frying a traditional *Rissol*, by replacing it with the oven regeneration, may be an alternative, in order to obtain an acceptable consumer product and nutritionally more suitable. In general, the use of a 0.5% (w/w) of hydrocolloid formulation added to the coating system offers a better alternative for the production of an oven baked product. It was concluded that the formulations with 1.5% (w/w) of hydrocolloid showed a poorer appearance (with cracks and lumps) than the formulations with 0.5% (w/w). The results of the present study showed that carboxymethylcellulose in coating batter of *Rissol* regenerated in oven could be an alternative for reduction of total fat when compared to the traditional deep-fried process.

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