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Effect of Sodium Chloride Reduction and Wheat Fiber Addition on Chicken Nugget Quality

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Authors' contributions

This work was carried out in collaboration between all authors. Authors FP and PB designed the study and performed the statistical analysis. Authors RF, PB, FP and MGD performed product elaboration and laboratory tests. Author OT was in charge of getting materials and equipment. Author PB coordinated the experimental work, wrote the protocol and the manuscript and managed literature searches. Author GT supervised the study. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The effect of sodium chloride (NaCl) reduction and wheat fiber (F) addition on chicken nugget quality was analysed. Storage stability of a low sodium formulation was also determined.
Study Design: Thirteen batches of chicken nuggets were produced according to an arrangement based on a Central Composite Design. In the storage stability study, two batches were elaborated. One batch was similar to products currently marketed; the other batch was selected according to the previous results. These nuggets were stored in a freezer for twelve months.
Place and Duration of Study: Laboratorio de Industrias Cárnicas, Facultad de Ciencias de la Alimentación, Universidad Nacional de Entre Ríos, Concordia, Argentina, between July 2012 until October 2015.
Methodology: Chicken nuggets with the addition of sodium chloride (0.5 – (to) 1.9%) and wheat fiber (0 – (to) 2%) were prepared. Physico-chemical parameters such as PH, cooking loss, texture,

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color, fat, protein and moisture were determined. The effect of NaCl and F on these parameters was analyzed using response surface methodology. A sensory test was also conducted by consumers (60) who evaluated overall acceptability. Storage stability of two batches (Batch 1: no F and 1.6% NaCl; Batch 2: 2% F and 0.8% NaCl) was measured by performing TBARS, microbial counts and descriptive sensory test (14 trained judges) for rancid characteristics. Data was analyzed with ANOVA.

Results: The reduction of NaCl significantly affected pH, moisture, cooking loss and whiteness (P=.05) of chicken nuggets. Moreover, F addition significantly affected pH, moisture and hardness (P=.05). No differences between batches (P>.05) were found in overall acceptability. No changes (P>.05) were found in lipid oxidation and microbiological counts between 2% F + 0.8% NaCl sodium and control nuggets during frozen storage.

Conclusion: The reduction of NaCl by 50% and the addition of 2% fiber improved the quality of chicken nuggets. These chicken nuggets had less cooking loss, tenderer characteristics and a slight decrease in whiteness without affecting consumer acceptability or storage behavior.

Keywords: Chicken nugget; healthier product; reduced sodium; wheat fiber; consumer acceptability; storage behavior.

1. INTRODUCTION

Poultry meat production in Argentina has grown by 93% in the past ten years [1] due to an increase in domestic consumption and exports. Local consumption of poultry meat is mainly based on whole chicken although there is a growing trend towards cut up and processed products. Less time spent on meal preparation has increased consumption of prepared foods such as chicken nuggets [2]. Increased demand has led to a continuing need to use new materials and technologies to improve their characteristics and yields [3].

Meat and meat products are important sources of protein, fat, essential amino acids, minerals and vitamin and other nutrients [4]. Sodium chloride (NaCl) is one of the sources of sodium in meat products and its reduction is an important objective to decrease the total sodium diet [5]. Depending upon eating habits, approximately 20–30% of common salt intake comes from meat and meat derivatives in western countries [6].

Table salt is important in human physiological functioning. The main chemical component in common table salt, sodium, is an essential nutrient necessary for maintenance of plasma volume, acid-base balance, transmission of nerve impulses, and normal cell function [7]. However, excessive salt intake may cause health problems: kidney disease, water retention and high blood pressure [8]. In general, people tend to reduce the amount of NaCl in the diet because they are conscious about the adverse effects of excessive salt intake.

National and international organisms and authorities struggle to reduce salt in foods as an effective strategy to improve the health of the population. The Institute of Medicine of the United States makes different recommendations to reduce sodium intake [9], such as the development of new low-sodium products or reformulation of existing ones.

The addition of NaCl in the formulation of meat products would improve their aroma and flavor, preservation and consistency [10]. With respect to flavor, this compound plays a significant role in the taste of the meat products [11]. Sodium chloride action on myofibrillar proteins improves binding properties after cooking resulting in a desirable texture gel [12]. Salt preservation effect would extend the shelf life of the product mainly due to low water activity [13,14].

The use of salt in this type of products may be due to technological benefits during processing, such as increased hydration of proteins and their solubility [15]. Salt helps water and fat binding capacity, so that a reduction in its content may cause side effects such as increased cooking loss and texture impairing [8].

These are some of the factors that determine the use of sodium chloride; however, flavor perception is the reason why sodium is not reduced in food processing. Four out of ten consumers believe low sodium products do not have the same taste as the original product [16]. Nonetheless; consumers show a positive attitude towards reduced sodium meat products [17].

Moreover, the product will also become healthier with dietary fiber addition. Fiber ingestion has an important role in maintaining a normal laxative effect and in the microbial population of the large intestine [18]. Furthermore, gastrointestinal tract diseases, diverticulitis, hiatal hernia, gallstones, appendicitis, colon cancer, cardiovascular disease, obesity and diabetes have low incidence in populations consuming fiber-rich diets.

A study by Castañola et al. [19] on Argentinian adolescent's diet shows that only 1% consumes five servings containing the minimum dietary fiber recommended intake. Chicken nuggets are preferred by children and adolescents; if fiber is added to these snacks, they could improve their diet.

If sodium chloride is reduced and fiber is increased in chicken nuggets, physicochemical and/or sensory characteristics could change. Water is the major component of these products; a variation in water retention capacity implies different processing yields, being this a very important economical aspect [2].

Food sensory attributes are highly relevant for industry because they have a high impact on consumers purchase decision. Therefore, quality controls should be implemented to avoid acceptability issues.

Formulation changes on chicken nuggets could impact chicken nuggets safety or spoilage. In addition, lipid oxidation reactions during the preservation period should be also considered.

The aim of this study is to evaluate the effect of NaCl reduction and F addition on physicochemical parameters and sensory attributes of chicken nuggets. Storage stability of a selected formulation is also analyzed.

2. MATERIALS AND METHODS

2.1 Materials

Chicken breast meat was purchased from a local market (Super Vea, Concordia, Argentina). All analytical grade chemicals (such as hexane, sodium hydroxide, hydrochloric acid and petroleum ether) were p.a. quality obtained from Cicarelli (Argentina).

2.2 Methods

2.2.1 Experimental design

Thirteen batches of chicken nuggets were produced according to the combinations of levels factors (quantity of NaCl and F) and random order resulting from the application of a central composite design (CCD). Amounts of NaCl and F in each batch are shown in Table 1.

Table 1. Sodium chloride and wheat fiber percentage (%) on wet basis (wb) in each batch of chicken nuggets

Batch (nº)	Wheat fiber (% wb)	Sodium chloride (% wb)
1	1,0	1.2
2	1.7	0.7
3	0.3	0.7
4	1.0	1.2
5	0.0	1.2
6	1.0	1.2
7	1.0	1.9
8	1.0	0.5
9	2.0	1.2
10	1.0	1.2
11	1.7	1.7
12	0.3	1.7
13	1.0	1.2

The ranges of variables used to generate the CCD are shown in Table 2. They were based on technical literature data and the performance of preliminary experiments.

Table 2. Ranges of variables used to generate the central composite design

Variables	Symbols	Variable levels	
Sodium chloride (%)	NaCl	0.7	1.7
Wheat fiber (%)	F	0.3	1.7

2.2.2 Nugget processing

The manufacturing process was carried out in the pilot plant by mixing minced chicken breast meat (71.5%), with spices white pepper, oregano, thyme and garlic, and additives regularly used for commercial nuggets. The wheat fiber (J. Rettenmaier & Söhne GmbH & Co, Inmobal-Nutrer, Argentina) comprised insoluble dietary fiber (945 g), soluble dietary fiber (25 g), moisture (80 g), fat (2 g), protein (4 g) and ash (<30 g) per kg of product (information provided by the manufacturer). NaCl was replaced by a potassium chloride and magnesium chloride mix (50/50). When wheat fiber was added, the fat matter (butter) was removed.

All components were thoroughly mixed using a blender. Next, the mixture was extended in a thin layer (10 mm thickness), frozen (24 h) and shaped into discs (4 cm diameter). The obtained units were breaded and fried in sunflower oil (180ºC) until 71ºC internal temperature was reached. Finally, nuggets were kept frozen in zip lock bags.

2.2.3 Analytical procedures

Fat and protein content of chicken nuggets were determined in triplicate according to methods described by AOAC [20], using a 2055 Soxtec (Foss Tecator, Sweden) and 2200 Kjeltec auto destillation (Foss Tecator, Sweden), respectively.

The pH was determined in quadruplicate using a pH meter with puncture electrode (Oakton, Singapore) and moisture was determined according to the method described by AOAC [20].

Four samples of each batch were weighed before (P1) and after (P2) the frying process, calculating Cooking loss (%) by the equation (P1 – P2) x 100 / P1.

Warner Bratzler shear test and texture profile analysis (TPA) were carried out, computing hardness (WB, N), cohesiveness, springiness and chewiness [2] with six repetitions for each batch.

Lightness L*, redness a* and yellowness b* of nugget samples were evaluated with a Minolta CR-300 (Minolta Camera Co. Osaka, Japan), light source D65 and 2º viewed angle. Measures were taken on three nuggets at six sites on the inner longitudinal cut, calculating whiteness (W) by the equation $100-[(100-L^*)^2+a^{*2}+b^{*2}]^{0,5}$.

Overall acceptability was evaluated by panels constituted by regular nugget consumers (60) through a hedonic test, by means of a 10 cm unstructured scale, ranging from "dislike very much" (0) to "like very much" (10). Panelists were 18-30 year old students from the Facultad de Ciencias de la Alimentación, in Concordia, Entre Ríos. Each sample, coded with random four digit numbers, was previously heated for six minutes on each side in an electric oven at 180º C (as recommended for commercial products).

2.2.4 Storage stability study

In this trial, two nugget batches were prepared following the same manufacturing process mentioned in 2.2.2. One batch, with no wheat fiber and contained 1.6% sodium chloride (standard value of products currently marketed), was considered as control batch (Batch 1). The other batch (Batch 2) was prepared based on the feasible optimum condition obtained using the statistical software. Batch 2 was prepared with the addition of 2% wheat fiber and 0.8% sodium chloride. Nuggets were stored in zip-lock bags, in a freezer at -18±2℃ for twelve months.

Lipid oxidation of chicken nuggets was determined by measuring the 2-thiobarbituric acid reactive substances (TBARS) values, according to the method described by Rosmini et al. [21]. Results were expressed as mg malonaldehyde equivalent / kg sample. This analysis was carried out on nuggets after 2, 4, 8, 10 and 12 months storage. TBARS determinations were performed in quadruplicate, on samples from three nuggets for each batch, previously thawed for 24h at 4±2℃ and homogenized in a food processor (Moulinex, 700W).

For microbiological counts, Thatcher and Clark [22] techniques were adapted. Nuggets were thawed (24h, 4±2℃) in sterile packaging. Sample preparation was carried out under laminar flow chamber in sterile bags, and homogenous distribution was assured by means of a bag mixer (Masticator, IUL Instruments). All determinations were performed in duplicate at 24 h of nugget processing and after 2, 4, 6, 8, 10 and 12 months storage. Counts were expressed as colony forming units per gram of sample (CFU / g). For total aerobic mesophilic count, samples were plated on Rida® Count (R-Biopharm AG, Germany) using 10^{-2} and 10^{-1} dilutions. Psychrophilic counts were performed by pour plate method using plate count agar (PCA) with 10^{-2} and 10^{-1} dilutions. Presence or absence of Salmonella in 25 g sample was monitored, in broth previously enriched with tetrathionate and subsequent plating in Salmonella Shigella Agar (Britania, Argentina).

Sensory evaluation was carried out through a descriptive test, based on the method described by Lawless and Heymann [23]. Nugget evaluations were performed by a group of panels consisting of 14 trained judges, after 2, 4, 6, 8, 10 and 12 months of frozen storage. Three digit coded samples were previously heated in an electric oven at 180℃ for six minutes on each side during each session. Each sample was evaluated with a protocol sheet, using an unstructured linear scale, for rancid aroma and rancid flavor attributes (lower classification: nonexistent value 1; top: very strong, value 7).

2.3 Statistical Analysis

All data were expressed as mean ± standard deviation (SD).

The effect of different amounts of NaCl and F on chicken nuggets quality characteristics (except overall acceptability) was evaluated using response surface methodology (RSM). Model validation was carried out using ANOVA, checking the significance of all effects.

Overall acceptability results (consumer panel) and the quantitative descriptive test (trained judges) as well as storage stability data were evaluated using ANOVA.

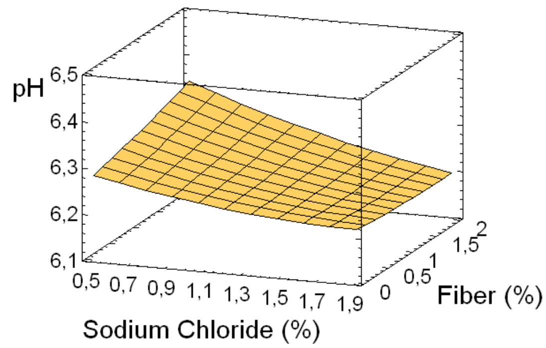
All statistical analyses including graphical response surface models were performed using Statgraphics Centurion XV (StatPoint Tech, Inc., Warrenton, VA, USA). P < 0.05 was considered a significant difference.

3. RESULTS AND DISCUSSION

Chicken nugget pH ranged from 6.18 to 6.34, in agreement with Perlo et al. [24]. RSM indicated that pH was significantly affected by NaCl (*P = .003*) and F (*P = .049*). The model adequately explains response variation with good R^2 values (R^2 = .75). It was observed (Fig. 1) that as chicken nugget NaCl decreases, pH increases. Results agreed with Ruusunen et al. [25] and Puolanne et al. [26]. High F levels produce a slight pH increase in cooked sausages manufactured with pig skin and wheat fiber as reported by Choe et al. [27]. This trend may be due to the pH of F (7.5).

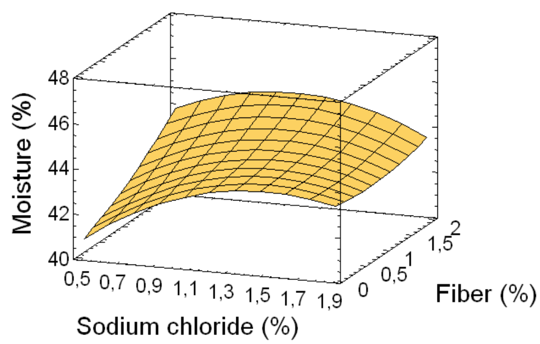
Moisture was significantly affected by F (*P = .025*) although R^2 values were low (R^2 = .32). The higher moisture values relate to intermediate amounts of NaCl and high F (Fig. 2). In addition cooking loss was only significantly affected by NaCl (*P = .013*), with satisfactory R^2 values (R^2 = .60). Similar to moisture behavior, it showed the minor cooking loss for intermediate values of NaCl and the maximum percentage of F (Fig. 3).

Dietary fiber is known to have good hydration properties, improving cooking yield in meat products [28]. Nevertheless this effect was not visible in our study.



pH = 6.33 – 0.11***NaCl** + 0.03***F** + 0.02***NaCl**^2 – 0.02***NaCl*****F** + 0.01***F**^2

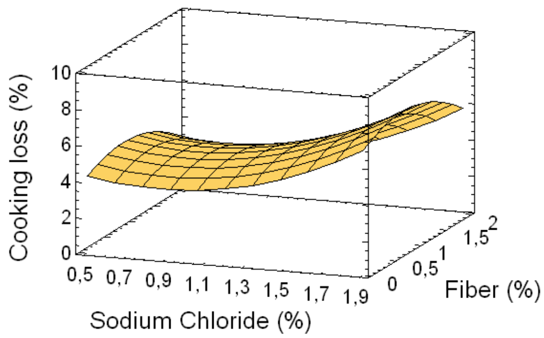
Fig. 1. Response surface plot for pH in chicken nugget, as a function of sodium chloride and white fiber along with the model equation predicting effects of the variables on pH



Moisture= 37.71 + 7.76***NaCl** + 1.43***F** – 2.54***NaCl**^2 – 0.96***NaCl*****F** + 0.27***F**^2

Fig. 2. Response surface plot for moisture in chicken nugget, as a function of sodium chloride and white fiber along with the model equation predicting effects of the variables on moisture

Chicken nuggets protein level was not significantly affected by NaCl (*P = .563*) and F (*P = .278*). Similarly, fat content was not significantly affected by NaCl (*P = .763*) and F (*P = .132*). Both models adequately explain response variation with good R^2 values (R^2 =.74 and R^2 =.83 respectively). Fiber addition to nuggets and other meat products affects protein percentage only when significant values are included in the formulation [27,29,30]. Moreover, fat content presents differences due to the incorporation of fiber in amounts higher than 15% [27,29] in this type of products. The amount of fiber addition (2% maximum) affects neither fat nor protein percentage of the final product in this study.

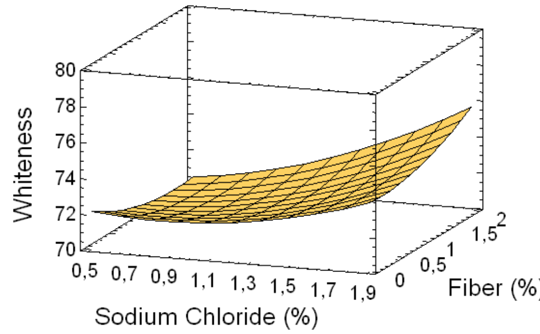


Cooking loss = 6.05 – 5.00***NaCl** + 1.72***F** + 2.87***NaCl**^2 + 0.14***NaCl*****F** – 1.26***F**^2

Fig. 3. Response surface plot for cooking loss in chicken nugget, as a function of sodium chloride (NaCl) and white fiber (F) along with the model equation predicting effects of the variables on Cooking loss

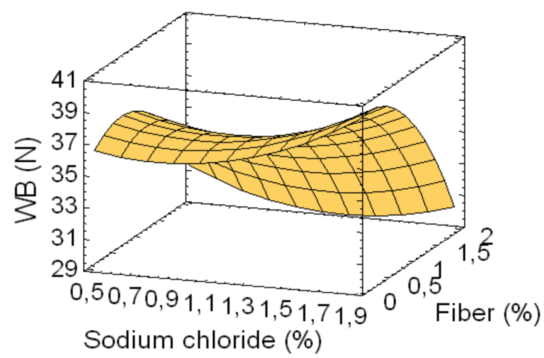
As for color data, W was found to be significantly affected by the amount of NaCl (*P* = *.035*), with slightly lower values for low-sodium formulations (Fig. 4), although the model presents low R^2 values (R^2 = .56) in this case. The added wheat fiber, with its clear color in white tones, did not decrease chicken nugget W, as in restructured fish products and surimi [31,32]. Results could be related to changes in pH values, since they decreased as NaCl increased. A decrease in pH makes chicken meat paler, whether raw [33] or cooked [34]. Whiteness is a parameter usually applied to surimi products. However, it was selected because chicken breast is similar to the white color of some fish species [35]. Hence W was preferred as a color quality indicator, being chicken nugget a restructured product like surimi manufactured foods.

WB chicken nugget values decreased significantly by F only (*P* = *.046*), as F content increased (Fig. 5). Again, the model displays poor R^2 values (R^2 = .40). TPA texture parameters were affected neither by NaCl nor F (R^2 > .75). Other studies on different meat products (coarsely ground, restructured, emulsions and gels) found textural properties (mainly hardness) decreased as the amount of F increased [29,31,36]. Wheat fibers were probably larger than matrix cells, thus disrupting the less homogenous protein network [32].



Whiteness = 73.17 – 3.00* **NaCl** – 2.54***F** + 1.76***NaCl**^2 + 1.21***NaCl*****F** + 0.59***F**^2

Fig. 4. Response surface plot for whiteness in chicken nugget, as a function of sodium chloride and white fiber along with the model equation predicting effects of the variables on whiteness



WB = 3.92 – 0.57***NaCl** + 0.43***F** + 0.34***NaCl** ^2 – 0.16***NaCl*****F** – 0.30***F**^2

Fig. 5. Response surface plot for WB in chicken nugget as a function of sodium chloride and white fiber, along with the model equation predicting effects of the variables on WB

Consumers found no significant differences between batches (*P* > *.05*) in the sensory test, with a 7.6±1.4 mean score of overall acceptability. Poultry meat has neutral flavour, light color and consistent texture [37]. These characteristics enable chicken meat products to acquire not only the desired flavor profile and/or texture [38] but also functional properties according to target consumers. Sarıcoban et al. [39] found that lower addition of wheat bran and NaCl to patty resulted in higher acceptable products with regards to overall quality properties.

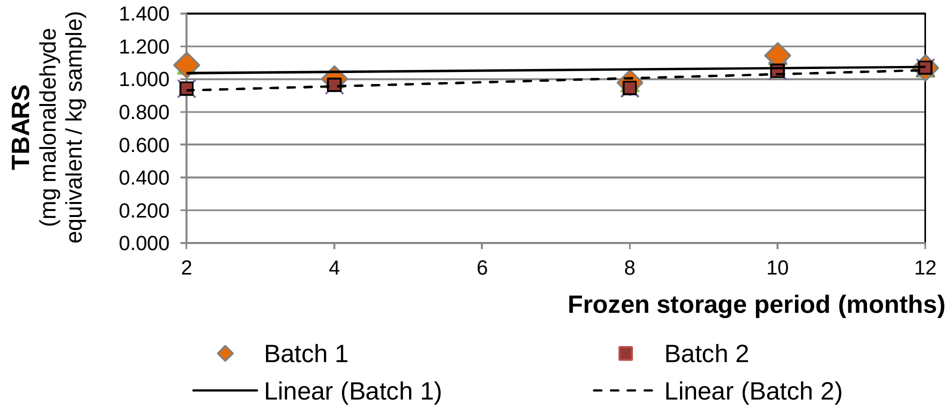


Fig. 6. Evolution of TBARS in chicken nuggets during frozen storage

Batch 1: 0% of wheat fiber and 1.6% sodium chloride
Batch 2: 2% of wheat fiber and 0.8% sodium chloride

The storage study showed that TBARS remained constant over the study period, with no significant differences between the values for each batch ($P > .05$). Although Batch 2 TBARS were always below the ones in Batch 1 (Fig. 6 above), no significant differences between them ($P > .05$) were observed for each period.

In addition, judges did not perceive rancid aroma or rancid flavour. Rancid aroma and rancid flavour mean values were 1.4±0.5 and 1.5±0.8 for Batch 1, and 1.7±0.9 and 1.4±0.5 for Batch 2, respectively, with no differences ($P > .05$) between formulations or in the storage period.

As regards microbiological analyses, total mesophilic aerobic count was not affected by NaCl reduction or the 2% added wheat fiber during storage. No significant differences between Batch 2 and Batch 1 total counts ($P > .05$) were observed for each period. In addition, total count showed no variation ($P > .05$) during the storage period for each batch.

Total mesophilic aerobic counts were low for both batches (0.1 – 4 UFC/g x 10^2) during the test. These counts are far below the recommended limit for human consumption (10^6 UFC/g, [40]).

Psychrophilic microorganisms were not detected in either batch during frozen storage. Moreover, Batch 1 and Batch 2 analyses indicated absence of Salmonella during the 12 month control.

It is remarkable that none of the samples showed superficial fungal disorders during storage.

4. CONCLUSION

Fiber addition seems to mask sensory acceptability problems in reduced sodium chicken nuggets. It also appears to be a good alternative for replacing, to some extent, salt functional properties. According to results, 50% or less sodium chloride could be reduced in nugget formulation, adding 2% wheat fiber to a product with less cooking loss, tenderer characteristics and a slight decrease in whiteness, without affecting consumer acceptability.

Lipid oxidation and microbiological count in nuggets with 0.8% sodium chloride and 2% wheat fiber were not a limiting factor for frozen stability. In addition, neither rancid aroma nor rancid flavours were found during storage due to the selected formulation.

This is a promising approach for producing reduced sodium nuggets with added wheat fiber.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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