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Effect of the addition of manioc starch, water and inulin on the technological characteristics of bicuda pâté (Sphyraena tome, Fowler, 1903)

Efecto de la adición de almidón de mandioca, agua e inulina sobre las características tecnológicas del paté bicuda (Sphyraena tome, Fowler, 1903)

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ABSTRACT

Fish and fish products are an outstanding source of essential protein and micronutrients. In cured meats, such as pâté, the technological characteristics are fundamental to the final quality of the product. The present study aimed to evaluate the effect of the addition of manioc starch, water and inulin on moisture, water holding capacity (WHC) and texture profile in pâtés using the underutilized marine fish bicuda (barracuda, Sphyraenatome) with total fat replacement by inulin. A Rotational Central Composite Design (RCCD) was used with the independent variables inulin, manioc starch, and water. Water, inulin, and manioc starch significantly influenced ($p<0.05$) the moisture content of pâtés, WHC, and texture, hardness, gumminess, and chewiness parameters. The technological action of inulin as a substitute for fat used in the formulations (3% to 6%) was underestimated. The percentages used were below perecentages of at least 20% of fat reported in the literature.Current legislation does not recommend WHR values and hardness parameters, only values for humidity. There is a need for revision of legislation to meet the characteristics of the identity pattern and quality of fish pâté.

Keywords: Inulin; Fish pâté; Fishery products; Poached-bicuda; Technological properties.

RESUMEN

El pescado y los productos pesqueros son una fuente excepcional de proteínas esenciales y micronutrientes. En embutidos (carne curada) como el paté, las características tecnológicas son fundamentales para la calidad final del producto. El presente estudio tuvo como objetivo evaluar el efecto de la adición de almidón de mandioca, agua e inulina sobre la humedad, la capacidad de retención de agua (WHC) y el perfil de la textura en patés fabricados con peces marinos subutilizados (barracuda, Sphyraena tome) con reemplazo total de grasa por inulina. Se utilizó un diseño compuesto central rotatorio (RCCD) con las variables independientes inulina, almidón de mandioca y agua. El agua, la inulina y el almidón de mandioca influyeron significativamente ($p<0.05$) en el contenido de humedad de los patés, WHC, y los parámetros de textura, dureza, gomosidad y masticabilidad. Se subestimó la acción tecnológica de la inulina como sustituto de la grasa en los contenidos utilizados en las formulaciones (3% a 6%). Los porcentajes utilizados estaban por debajo de lo que informa la literatura de al menos un 20% de grasa. La legislación actual no recomienda valores de WHR y parámetros de dureza, solo valores de humedad. Es necesario revisar la legislación para cumplir con las características del patrón de identidad y la calidad del paté de pescado.

Palabras clave: Inulina; Paté de pescado; Pescados-bicuda; Productos de la pesca; Propiedades tecnológicas.

INTRODUCTION

Fish and fish products are major allies of consumer health as they represent an excellent source of protein and essential micronutrients contributing to an adequate and balanced diet. Proteins that are present in fish represent an essential factor in the diets of some high population countries where the total amount of protein consumption may be below recommended levels[1,2].

The Food and Agriculture Organization of the United Nations[2] has expressed concern about the overexploitation of fish species of global economic importance with a consequent reduction in the capture of target species contributing to an imbalance between the global fish supply and demand. The organization pointed out the fact that one of the most important and promising alternatives to be considered is the use of accompanying fauna species and those of low commercial value both in industrial and artisanal fisheries for the development of new marine fish products of nutritional and sensorial interest such as cured meat (linguiça, sausage, and pâté).

The use of viable and applicable technologies is an excellent way to add value to underutilized species and contribute beneficially to the diet of the current world population providing protein and convenience foods with added value to these individuals[3,4]. From the nutritional point of view, the health of the population benefits, with the increased consumption of products with functional properties, through the addition of food ingredients that confer this characteristic. From the nutritional point of view, the health of the population benefits, with the increased consumption of products with functional properties, through the addition of food ingredients that confer this characteristic.

As a result, inulin has stood out due to its prebiotic action and by acting as a potent food ingredient being widely used in the food industry for the preparation of new products[5].

Inulin is a food ingredient that is part of the family of carbohydrates known as fructans.It is widely used in the world market and can be used for a variety of purposes, including as a fat and sugar replacement, a bulking agent for low calorie products, and a texturizing agent[6,7,8]. Cassava (manioc) starch is also widely used in meat products with the aim of increasing yield and improving the texture of the product by strengthening mass elasticity[3].

For cured meat such as pâté, moisture parameters, water holding capacity and texture profile are critical to the final quality of the product.Determining the moisture content in products of animal origin is important since the free water content is closely related to its chemical composition and stability influencing enzymatic, microbiological, and chemical deterioration mainly during storage or depository.

Water holding retention (WHR) refers to the ability of the product to retain moisture or water during the application of external forces such as cutting, heating, and grinding and directly reflect the sensory quality of the final product[9].

The present study aimed to evaluate the effect of the addition of inulin and manioc starch in the parameters of moisture, water retention capacity and texture of pâtés developed from hake.

MATERIALS AND METHODS

Raw material

Specimens of the underutilized marine fish species bicuda (Sphyraenatome) were provided by fishermen from the municipality of Itaguaí, Rio de Janeiro (RJ), Southeast Brazil.Mechanically separated fish meat (fish flesh and deboned fish) (MSM) was produced on the same day of the fish capture.Fish was supplied clean (headless, gutted, and split) and transported in isothermal crates packed with ice. An automated eviscerator (Mec Fish, Brazil) was used to produce MSM from splitted fish.MSM was produced and then packed in plastic bags that were later weighed, identified (18 tests) and vacuum sealed using model 200B (Selovac, Brazil). Packed MSM was stored in a freezing chamber at -18 °C and used in pâté processing.

Experimental Design and Statistical Analysis

In the present study, we used response surface methodology with a Rotational Central Composite Design (RCCD) composed of 8 points corresponding to a complete factorial test[2,3] plus 6 axial points (2x3) and 4 central points summing up a total of 18 trials as shown in tables 1 and 2. Water, inulin, and manioc starch percentages were used as independent variables.The response variables were: (i) moisture content, (ii) water retention capacity, and (iii) texture profile. A second order polynomial model was used to adjust experimental responses as a function of independentvariables:

$$y= \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \varepsilon$$

In the formula, y represents the response variable,β_0 is the general mean of the responses for a given variable,β_1, β_2 and β_{12} are the linear coefficients,β_{11} and β_{22} are the quadratic coefficients of the equation,x_1 and x_2, the independent variables and the experimental error, respectively.

Analysis of Variance (ANOVA) test with p= 0.05 for each response variable was used to determine the linear, quadratic, and interaction coefficients. The F values were compared, calculated and tabulated for each variable in order to verify if the data fit the model. Regression coefficients were used to generate response surfaces and contour plots.

Formulation and weighing of ingredients

The following ingredients were used in the formulation of pâté: MSM from bicuda, water, inulin, manioc starch, soy protein, refined salt, garlic, onion and white pepper, sodium erythorbate, polyphosphate, and curing salt.

These ingredients were obtained from commercial establishments located in the municipalities of Rio de Janeiro and Seropédica, RJ, Southeast Brazil. The amount of MSM varied according to the concentration of water, inulin, manioc starch whereas the other ingredients had fixed values. The ingredients were weighed at the fermentation laboratory of the Food Technology Department of the Federal Rural University of Rio de Janeiro (DTA/ IT/UFRRJ) and transported

Table 1. Process variables and levels that were used in experimental planning.

Independent variables	Levels -1.68	-1	0	+1	1,68
Water (%)	15	18	22.6	27	30
Inulin (%)	3	3.6	4.5	5.4	6
Manioc starch (%)	0	2	5	8	10

Table 2. Matrix of the experimental design for the 18 tests with the coded and real (actual) values.

Essay	X1	X2	X3	Water concentration (%)	Inulin concentration (%)	Cassava starch concentration (%)
1	-1	-1	-1	18	3.6	2
2	+1	-1	-1	27	18	2
3	-1	+1	-1	18	5.4	2
4	+1	+1	-1	27	5.4	2
5	-1	-1	+1	18	3.6	8
6	+1	-1	+1	27	3.6	8
7	-1	+1	+1	18	5.4	8
8	+1	+1	+1	27	5.4	8
9	-1.68	0	0	15	4.5	5
10	1.68	0	0	30	4.5	5
11	0	-1.68	0	22.6	3	5
12	0	1.68	0	22.6	6	5
13	0	0	-1.68	22.6	4.5	0
14	0	0	1.68	22.6	4.5	10
15	0	0	0	22.6	4.5	5
16	0	0	0	22.6	4.5	5
17	0	0	0	22.6	4.5	5
18	0	0	0	22.6	4.5	5

on the day of processing to Embrapa-RJ with the exception of MSM that was weighed prior to homogenization at the Embrapa-RJ fish plant.

Pâté preparation

Ingredients were placed in homogenization equipment. Firstly, frozen MSM was added and ground in milling equipment (Multiprocessor, Auto-iq Turbo Smooth, USA) for 30s, and crushed one time. The other ingredients were then added (water was the last ingredient added) and homogenized for an additional 60s. After homogenization, the prepared dough was placed in a round plastic container and transferred with a stainless steel spoon to tinplate cans (a two-piece package with easy open closure and a diameter of 83 m) and weighed. Cans were filled with 170 g of pâté. The 18 trials were performed with 3 replicates. Cans filled with pâté were closed usinga sealing machine (Since Dixie, USA). After sealing, cans were placed inside an autoclave. The time-temperature ratio used to commercially sterilize the product was 115 oC/15 min resulting in a F_0 of 6 min in

which	z= 10 ºC

For safety purposes and control of the process, thermocouples were introduced in two cans conditioned in different sites inside the autoclave.

Response variables

The variables evaluated included moisture percentage, water holding capacity (WHC), and instrumental texture. Moisture and WHC analyses were carried out at the Fermentation Laboratory at the DTA/UFRRJ. Texture profile analysis was performed at the Sensory Analysis Laboratory of the Federal Center for Technological Education Celso Suckow da Fonseca (CEFET/RJ), Valença, RJ, Southeast Brazil.

Moisture

Humidity was determined by the greenhouse gravimetric method at 105 °C[10].

Water Holding Capacity (WHC)

WHC was assessed according to an adapted methodology[11]. 10 g of each sample in glass vials with a capacity of 40 ml were weighed. Vials were then closed (capped) with a screw closure and heated in a water bath (CapLab Comercial®) at 90 °C for 10 min. Vials were then taken out of the water bath and samples were cooled at room temperature. Samples were removed from the vials with tweezers and placed in centrifuge tubes containing Whatman n.40 quantitative filter paper and cotton. Next, samples were centrifuged at 3,000 rpm for 15 minutes (FANEN-SP® Model 204-N Centrifuge, Brazil), cooled again and reweighed. The results obtained were based on the following formula:

$$\% \text{ WHC} = 1 - A - D \times 100\ U$$

in which: WHC= water holding capacity; A= weight of the sample in g before heating;D= sample weight in g after heating and centrifugation; U= total moisture in the sample expressed in percentage.

Texture Profile

The instrumental texture was evaluated using a texturometer model TA.XT Express Enhanced (Stable Micro Systems) with a cylindrical probe P/0,5[12]. The pâtés were analyzed inside the original and opened cans. The can was 83 cm in diameter with a height of 4 cm. The probe penetrated the pâté 3 consecutive times at different locations at a 10 mm comprehension distance (25% of initial height) with the following conditions: pre-test velocity= 5.0 m/s; test speed= 5.0 m/s; post-test velocity= 5.0 m/s; contact force= 5g. The analyzed parameters were: hardness, cohesiveness, elasticity, guminess, and chewiness. Hardness was obtained by the first force peak in the first compression. Cohesiveness was calculated by the ratio of the second compression area to the first compression area (A2/A1). Elasticity was defined by the ratio between the distance traveled in the area of the second compression cycle by the distance traveled in the area of the first compression cycle. Gumminess was determined by multiplying hardness by cohesiveness.Chewiness was obtained by multiplying the elasticity values by the gumminess[13].

Statistical analyses

The results obtained from the analyses of the dependent variables were analyzed using the Response Surface Methodology with the STATISTICA® software.

RESULTS

Moisture

It was observed that the analyzed variables water, inulin, and cassava starch percentages had a significant influence ($p<0.05$) on the moisture content of pâté.It was also noted that the most suitable moisture content, according to the current legislation, tend to be obtained by increasing manioc starch and inulin concentrations and reducing water content.

Therefore, the use inulin concentration of a least 4.5% and manioc (cassava) starch concentration of at least 5% would be sufficient to reach the maximum moisture content of 70% set for pâté by legislation[14]. Therefore, lower concentrations of inulin and manioc starch might increase moisture content, extrapolating the limits established by the current legislation.

In the analysis of variance of the RCCD for water, inulin, and manioc starch concentrations in the moisture content, it was noted that the calculated F (1.03) was lower than the tabulated F (3.09). Thus, we were unable to validate the proposed model ($p> 0.05$).

Water Holding Capacity (WHC)

The independent variables of water, inulin, and cassava starch in the range studied significantly influenced ($p<0.05$) the WHC content of pâté.In the analysis of variance of the RCCD for water, inulin, and cassava starch concentrations in the WHC content of the pates, we observed that the calculated F (105) was greater than the tabulated F (3.34). Therefore, we were able to validate the proposed model ($p <0.05$). Higher WHC values would be desirable and would avoid the occurrence of syneresis in this product. It was noted that both variables - cassava starch percentage and inulin percentage - presented a positive linear effect indicating the need to use a higher concentration of cassava starch and inulin in order to increase WHC (Figure 1).

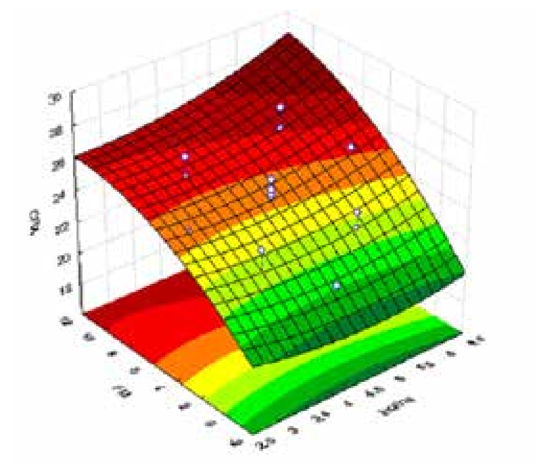

Figure 1: Response surface of WHC (%) as a function of cassava starch and inulinconcentration.

Texture profile

The results for the parameters of hardness, cohesiveness, elasticity, gumminess, and chewiness were assessed. Water, manioc starch, and inulin percentages significantly influenced ($p<0.05$) hardness, gumminess, and chewiness parameters.

Hardness

The independent variables of water and manioc starch percentages had a significant effect on pâté hardness ($p<0.05$). However, inulin percentage did not show any significant effect ($p>0.05$). In the analysis of variance of the RCCD for water, inulin, and cassava starch concentrations in the hardness value of the pâtés, it was observed that the calculated F (65.5) was greater than the tabulated F (3.68) which allowed us to validate the proposed model ($p<0.05$).

Figure 2 shows that in order to obtain lower hardness values that would be most suitable for pâté the percentage of water should have its concentration increased and the concentration of manioc starch reduced. However, with the increase in water concentration there would be an increase in the value of humidity and the maximum moisture limit established by the current legislation for pâté could be extrapolated[14].

Gumminess

It was noted that the independent variable percentage of water and manioc starch significantly influenced ($p<0.05$) the gumminess content of the pâtés and the percentage of inulin did not show any significant effect ($p>0.05$). It was observed through the analysis of variance that the calculated F (105) was superior to the tabulated F (3,68). Thus, we were able to validate the proposed model ($p<0.05$).

Gumminess is the energy required to disintegrate (grind, chew, masticate) food to the size that the individual is able to swallow it. Therefore, the lower the gumminess, the less effort and energy required to disintegrate food during the chewing and swallowing process. Thus, smaller gumminess tends to be the most indicated characteristic for pâté.

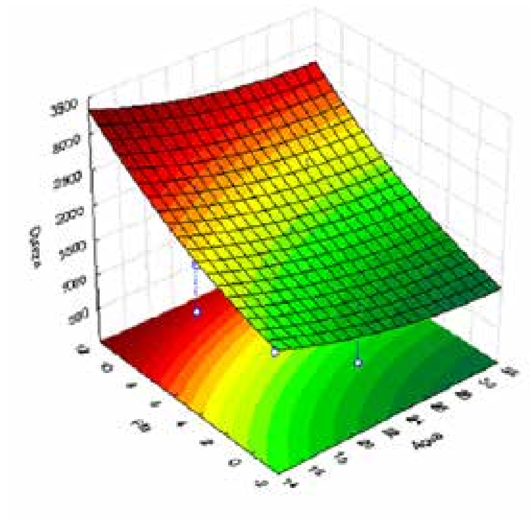

Figure 2: Hardness response surface (%) as a function of cassava water and starch concentration.

Figure 3 shows that lower gumminess values were obtained when water concentration was increased and the cassava starch concentration reduced. The analysis of the results for the moisture variable shows that it was necessary to reduce water concentration to 15% in order to meet the TRIQ (Technical Requirement of Identity and Quality) of pâté which establishes the maximum humidity content of 70%. Therefore, it is advisable to use higher water concentrations as indicated by the results of the gumminess so that pâté remains in compliance with current legislation.

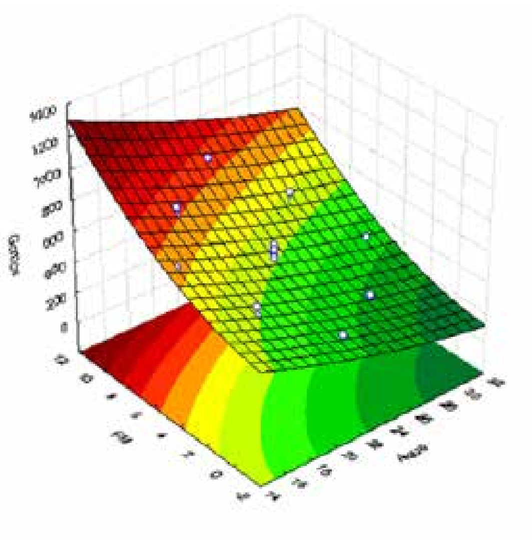

Figure 3: Response surface of the gumminess (g) as a function of water concentration and manioc starch.

Chewiness

Both the concentration of water and cassava starch significantly influenced ($p<0.05$) pâté chewiness.In the analysis of variance of the RCCD for the variables concentration of water, inulin and manioc starch in the chewability content, the calculated F (61.2) was greater than the tabulated F (3.68). Therefore, we were able to validate this model ($p<0.05$).

The observed results indicate that in order to obtain better chewiness values for pâté, the water concentration should be increased and the concentration of cassava starch reduced (Figure 4). In order to reach lower values of chewiness, water concentrations should remain between 22% and 30% and cassava starch amounts should be between 0% and 5%. However, as previously observed for gumminess, such change would excessively increase the moisture content of pâté.

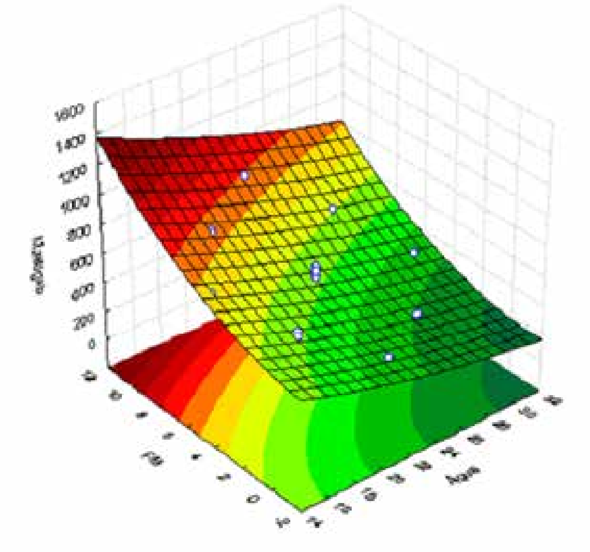

Figure 4: Surface of chewiness response (g) as a function of cassava water and starch concentration.

DISCUSSION

In the present study, we noted a decrease in the moisture content of pâtés due to an increase of the concentration of cassava starch and inulin. In contrast, the increase in the concentration of manioc starch and inulin resulted in an increase in the water retention capacity of pâtés. The results observed for the moisture variable are in agreement with those of the research study that used pork and goat meat to elaborate ready-to-eat ham products[15]. The product developed had a concentration of 2% manioc starch in its composition and its influence on the moisture content was studied. The study reported a significant linear influence ($p<0.05$) of the amount of starch in ham moisture. Authors concluded that the higher the amount of starch, the lower the moisture content of the product corroborating the results obtained in the current study. The addition of fat, inulin, and pectin substitutes in the development of Tuscan sausage with reduced fat content was evaluated in another study[16]. As for moisture, it was observed that the Tuscan-type sausage formulations that received inulin or pectin had lower moisture contents compared to the standard formulation in which fat substitutes (pectin or inulin) were not added. The effect of reducing moisture content when adding inulin was also observed in this study. The reduction in moisture content occurred due to the addition of inulin as this polysaccharide binds to water. The hydroxyl groups present in the molecular structure of inulin allow greater capacity to interact with water and also confer the ability to form stable gels[8]. Moisture contents below 70% for pâté are recommended as it meets the requirement established by the TRIQ for pâté and also relates to the lower water activity in the product.

With regard to WHC, which is a characteristic of quality of both meat and meat products, we may infer that cassava starch has a high-water retention capacity[9]. Cassava starch and oatmeal were used as fat substitutes in ovine meat hamburger formulation[17] and higher values of WHC were obtained. F3 and F4 formulations which received 2% manioc starch and 2% of oatmeal presented 73.8% and 68.6% WHC, respectively. Formulations F1 and F2, in which starch and flour were not added, presented 59.8% and 54.6% of WHC, respectively. The results obtained and reported in the study using cassava starch confirm the trends pointed out by the present study that the value of WHC tends to increase with the increase of manioc starch concentration.

The possibility of the elaboration of a beef burger with the addition of inulin as a substitute for fat and a functional prebiotic ingredient was evaluated[18] proving that the addition of inulin improved water retention of the hamburger. The conclusion on the influence of inulin concentration on WHC is similar to the results obtained in the present research study in which there is a positive linear effect of inulin concentration in WHC. WHC tends to increase in function of the increase of inulin concentrations.Inulin contributes to higher water retention due to its hydroxylated chemical structure. Regarding texture parameters, it was observed that inulin did not present any significant influence ($p>0.05$) on hardness, gumminess, and chewiness parameters.However, for the cassava starch, a significant effect was observed ($p<0.05$). Starch can increase firmness and other textural characteristics in products with reduced (low) fat content[19].

With regard to the technological action of inulin as a substitute for fat, it was observed that the contents used in the formulations studied (3% to 6%) did not allow the evaluation of this action since the percentages used were below those suggested in the literature that describes a minimum content of 20% fat. The amount of fat in a product such as pâté is between 20% and 60%. The use of extreme concentrations may compromise the final quality of the product[20]. The TRIQ of pâté establishes the minimum quality characteristics that this product must present in which humidity, fat, and maximum levels of total carbohydrates including starch are 70%, 32%, and 10%, respectively, and for protein the minimum established is 8%[14].

It is important to emphasize the fact that the current legislation for pâté (TRIQ) is not specific to fish pâté. Therefore, we were unable to compare the same standards of identity and quality with the products prepared with raw fish. There is a need to introduce changes in the legislation to specifically target products made with fish since these products are well accepted by the consumer market.

CONCLUSION

The variables water, inulin, and manioc starch concentration significantly influenced ($P<0.05$) WHC and parameters of texture, hardness, gumminess, and chewiness of bicuda pâté. Therefore, in order to obtain bicuda pâté with desirable characteristics including greater water retention capacity and lower humidity, the present study pointed to the use of higher concentrations of cassava starch and inulin and a reduction in water content.

In order to obtain lower values of hardness, gumminess and chewiness, the use of lower concentrations of cassava starch and higher water contents was suggested.

However, it should be pointed out that, for pâté, the current legislation does not recommend WHC values or hardness parameters, establishing only values for humidity.

The legislation should be revised to include specific characteristics for standardization of identityand quality of fish pâté.

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