Journal of Food and Nutrition Research, 2019, Vol. 7, No. 10, 751-758
Available online at http://pubs.sciepub.com/jfnr/7/10/9
Published by Science and Education Publishing
DOI:10.12691/jfnr-7-10-9

Diet Based on Food from the Colombian Andean Region Decreases C-reactive Protein, IL6, and Leptin in Women with Obesity

Elcy Yaned, Astudillo-Muñoz[1,2,*], Clara Helena González-Correa[1], Diana María, Muñoz-Pérez[1,2], Erika Martinez-Lopez[3], Daniel Camilo Aguirre-Acevedo[4], María Elena Alvarez Lopez[5]

[1]Department of Basic Sciences for Health, Research Group on nutrition, Metabolism and Food Security, Universidad de Caldas, Manizales, Colombia
[2]Department of Health Sciences, Care Management Group, Universidad Libre Pereira, Colombia
[3]Department of Molecular Biology and Genomic, Health Sciences University Center, University of Guadalajara, Guadalajara, Jalisco, Mexico
[4]Academic Group of Clinical Epidemiology, Institute of Medical Research, Faculty of Medicine, Universidad de Antioquia, Medellín, Colombia
[5]Department of Basic Sciences for Health, Research Group on Regenerative Therapy, Universidad de Caldas, Manizales, Colombia
*Corresponding author: elcyy.astudillom@unilibre.edu.co

Received September 17, 2019; Revised October 18, 2019; Accepted October 27, 2019

Abstract People with obesity develop low-grade chronic inflammation, which is characterized by a high serum concentration of inflammatory markers (CRP, IL-6, TNF-α, and leptin), which predisposes the development of chronic diseases. These markers can be modulated by a diet; therefore, a research project was developed to determine the effect of a diet based on foods available in the Colombian Andean Region, containing anti-inflammatory properties in obese women. A controlled study was conducted with 30 women. For eight weeks the experimental group received a diet based on food rich in fiber, polyunsaturated fatty acids, vitamins and polyphenols. The experimental group reduced the serum concentrations of CRP ($p = 0.005$), IL-6 ($p = 0.013$) and leptin ($p = 0.004$), in comparison with the control group. Therefore, the findings suggest that a diet based on foods available in the Colombian Andean Region with anti-inflammatory nutrients reduces CRP, IL-6 and leptin in obese women.

Keywords: *diet, inflammation, biomarkers, obesity, colombia*

Cite This Article: Elcy Yaned, Astudillo-Muñoz, Clara Helena González-Correa, Diana María, Muñoz-Pérez, Erika Martinez-Lopez, Daniel Camilo Aguirre-Acevedo, and María Elena Alvarez Lopez, "Diet Based on Food from the Colombian Andean Region Decreases C-reactive Protein, IL6, and Leptin in Women with Obesity." *Journal of Food and Nutrition Research*, vol. 7, no. 10 (2019): 751-758. doi: 10.12691/jfnr-7-10-9.

1. Introduction

Obesity is a chronic disease of multifactorial origin and is characterized by an excessive increase in body fat [1]. According to data from the World Health Organization (WHO), about 30% of the world's population, which corresponds to about 1.6 billion adults suffers from associated comorbidities, which generates more than one-third of deaths. The highest prevalence of obesity is found in women [2].

One of the factors that lead to the development of obesity is that, currently, there is a universal trend for the consumption of foods containing a high level of salt, carbohydrates, and refined sugars as well as fizzy drinks and saturated fat. All these products lack fiber, vitamins and other micronutrients which are important for the prevention of this disease [3].

Obesity is associated with a chronic low-grade inflammatory state, which involves an increase in serum concentrations of adipokines such as IL-6, TNF-α, leptin, and acute-phase proteins, such as CRP among others [4]. The inflammatory state influences the development of comorbidities such as diabetes mellitus type 2 (T2DM), arterial hypertension, dyslipidemia, stroke, and some types of cancer, such as that of the colon [5].

However, beneficial effects of diet have been found in the inflammatory state, because food provides bioactive components such as the fiber, polyunsaturated fatty acids, antioxidants such as polyphenols, all of which have anti-inflammatory effects; all these components can be obtained from simple plant and animal products like fruits, vegetables, legumes, fish and vegetable oils, that could be included in a preventive and therapeutic diet to treat diseases such as obesity [6,7,8]. This is why, currently, there is a great interest in knowing what the anti-inflammatory properties of feeding

patterns are their use in chronic disease prevention [9,10,11].

Colombia, particularly the coffee region (Risaralda, Quindío, and Caldas), has a wide variety of food, some of which contain bioactive components with anti-inflammatory effects which could be included in a preventive and therapeutic diet to combat obesity [6,8]. This has led to propose the design of a healthy diet based on food available in the Colombian Andean Region, with anti-inflammatory properties, which helps to prevent or modify inflammation and can contribute to the prevention of obesity.

2. Materials and Methods

2.1. Design of the Study

A study was carried out with a control group, with a non-probabilistic sample, based on a controlled dietary intervention. The calculation of the sample was estimated according to the expected changes, on which the high-sensitivity C-reactive protein (hs-CRP) was used as the main variable, to detect a change of 30%, with a significance of 95% and power of 80%. The values of the formula variables were taken based on a clinical trial [12].

The conformation of the groups was based on according to arrival such that; the participants were consecutively assigned to the experimental and control groups. Before the dietary intervention began, the two groups received a washing diet for a week, with a caloric distribution of 50-60% of carbohydrates, 15-20% of proteins, and 30-35% of total fat. The experimental group received the designed diet based on food with anti-inflammatory properties such as fiber, vitamins, polyphenols, and polyunsaturated fatty acids, coming from fruits, vegetables, legumes, fish, dark chocolate, whole grains, and peanuts, the caloric distribution consisted of 61% carbohydrates, 16% proteins, 23% fat and participants followed this diet for an eight-week period. Participants were given individual and group nutrition advice at the beginning and during this period. Each participant was provided with a personalized nutrition guide that contained information about portion sizes and suggested foods to be included in the diet. This was very varied to encourage a high number of participants to complete the project and achieve greater adherence to the diet. The control group continued with their usual diet consisting of 55% carbohydrates, 15% proteins and 30% total fat for the eight week period. They were also given a nutritional guide containing the portion sizes of the food that they used to consume before beginning the study.

To specify the size of the portions at home, a kitchen Kit was delivered that included a dish, a mug, a beaker; and measuring spoons for both groups. Additionally, the nutritional portions were standardized with all the participants using synthetic models, adapted according to the Colombian nutrition guidelines [13], so that they could provide a better report of the portions consumed during the intervention. Before the intervention, two food surveys were carried out (with a 24-hour reminder) on non-consecutive days of the week and one at the weekend, to determine the usual intake of all the participants. Additionally, 8 recordings were taken with a 24-hour reminder (one weekly) during the personalized controls, were recorded to evaluate adherence by estimating macro and micronutrient consumption during the intervention. In total, each participant completed 11 food surveys with a 24-hour reminder, were then analyzed using the program "Nutritionist Pro ®". Additionally, the participants in both the control and experimental groups recorded the number of portions consumed from each food group in a daily record format that was evaluated weekly by the researchers.

To monitor the participants involved in the experimental diet, two weekly telephone calls were made on different non-consecutive days during which questions related to the diet were answered (prices, purchases in supermarkets, recipes, restaurants, and menus). Additionally, a third weekly check was carried out in person with participants the experimental group to measure weight and a 24-hour reminder was filled in. Two Whatsapp messages were sent to the control group each week to ask them to record their daily intake and portion size of suggested food, they also had personalized, weekly check of weight and a food survey was taken to them with a 24-hours reminder. Both groups, the experimental and the control, were asked to try to maintain their usual weight, and not to make any lifestyle changes, especially those concerning physical activity. Weight loss or gain was estimated at a tolerable range of 1.5 kg during the intervention. The effects on inflammation were measured through the comparison between the serum concentrations of C-reactive protein, TNF-α, IL-6, leptin, and adiponectin before and after the intervention.

2.2. Selection of Participants

The participants were consecutively recruited from women who attended the bariatric surgery consultation at the Risaralda Clinic in Pereira, Colombia. All participants were told the objective of the research and a pre-clinical assessment was performed to determine if they met the inclusion criteria, according to which women aged 18 to 40 years old with a BMI of $\geq$ 30kg/m^2 were included. The criteria consisted of excluding women with a clinical history of diabetes, inflammatory diseases, consumption of anti-inflammatory drugs, oral contraceptives, vitamin supplements, hypoglycemic or lipid-lowering drugs, thyroid disorders, smokers, regular drinkers of alcohol (more than 2 glasses of wine of 150 ml/day or a glass of another alcoholic beverage with a higher degree of alcohol), and those, with psychological disorders that prevent the reliable collection of data, pregnant women, or those who were participants in weight loss programs were also excluded.

The individuals included in the study accepted that their participation was voluntary and signed the informed consent form. The recruitment of the participants began in January 2015 and ended in December of the same year. The study was approved by the Bioethics Committee of the University of Caldas (Acta 077) and adopted the guidelines set out in the Helsinki declaration for Human Research, in Resolution 8430 of 1993, title II, chapter I of the Ministry of Health of Colombia.

2.3. Design of the Dietary Intervention

The diet was designed to maintain the usual caloric intake of the participants and changes were only made in what refers to the quality and type of food, to maintain the usual weight of the participants. The percentage distribution of macronutrients of the experimental diet was 61% of carbohydrates, 16% of proteins and 23% of fats. It was recommended to replace 3 servings of regular food coming from refined flours, whit food containing at least 50% whole-grain cereal (rice, bread, arepa or crackers).

The daily consumption of 4 servings of fruit (400 g), 3 of vegetables (300 g) and a portion of peanuts (10 g) was recommended, as well as a weekly consumption of 3 cups (240cc) of sugar free dark chocolate, two portions of fish (200g), a portion of lean beef (100g), and 2 portions (100g) of legumes (beans, lentils, peas or chickpeas); also, 10g of canola vegetable fat was allowed to prepare their food daily and consumption of eggs was restricted to twice a week and a portion of sugar or panela (unrefined sugar) (10 g) was allowed daily. It was recommended to prepare the food with spices and to avoid the use of artificial seasonings and avoid the consumption of sausages, packaged food, fizzy beverages, bakery products, and factory produced sweets. The fruits suggested during the study were granadilla, guava, uchuva, black grape, papaya, pineapple, mango, orange, pear, tangerine, red apple, banana and strawberries, and only the following prepared as juice: passion fruit, blackberry, and lulo. As for the suggested vegetables, these were sugar snap beans, cucumber, red tomato, carrot, batavia lettuce, white onion, celery, spinach, and broccoli.

2.4. Anthropometric Measures

The participants were evaluated after a 12-hour fast. Anthropometric measurements were taken according to the protocol established by Lohman (1988), with a digital scale and a height rod brand Health or Meter®. With the weight and size data, the body mass index (BMI) kg/m² was calculated. Each measurement was carried out 3 times and the average value was used for the report of the final results.

2.5. Laboratory Test

To confirm the inclusion criteria, samples were taken for glycemia, thyroid-stimulating hormone (TSH) and blood (CH), which were analyzed with a SYSMEX team® XT-1800i and Hitachi Cobas 6000 Roche® equipment, respectively. Serum plasma concentrations of IL-6 and high-sensitivity C-reactive protein (hs-CRP) were processed in an IMMULITE® 2000 SYSTEMS from the SIEMENS Laboratory, through a sequential enzymatic immunometric assay in solid phase by chemiluminescent. Levels of leptin, TNF-α and adiponectin were measured using the sandwich-type ELISA technique, in an INVITROGEN® brand kit, following with the manufacturer's instructions, in a photometric Biotek® model EL800. Blood samples were extracted from the ulnar vein (5ml of venous blood), before to a 12-hour fast at the beginning and end of the study (weeks 0 and 8).

2.6. Statistical Analysis

Data were analyzed with the SPSS® software version 24.0 and the results were expressed as median and interquartile range. Interquartile variables were expressed through frequencies and categorical variables by percentages. The normal distribution of continuous variables was determined with the Shapiro-Wilk test. Intergroup differences were analyzed by a student detached t-test; by default, with the test of sums and ranges of Willcoxon. Inter-group differences were determined by the test t-student for independent samples, or the Mann Whitney U according to each case. Also, a covariance analysis (ANCOVA) was carried out to make adjustments using the baseline value. A p-value of less than 0.05 was considered statistically significant. The effect size was calculated with Z statistic, for non-parametric data [15] for the difference between the groups, assuming an effect in favor of the experimental group as "small" if the result was 0.1, "moderate" of 0.3, and "large" of 0.5.

3. Results

With a participant withdrawal estimate close to 7%, 35 women were recruited within an average age range of 29 ± 6.7 years, and a BMI of 36 ± 4.2 kg/m^2. An experimental group was formed (N: 18) and a control group (n: 17). During the intervention period, two people from the control group desisted from participating due to family problems. Three members of the experimental group were excluded, one due to pregnancy and two dues to failure to stick to the diet. Non-adherence to the diet was defined as an intake equal to or less than 65% of what was suggested. In total, 30 people completed the study (15 followed the experimental diet and 15 the control, Figure 1).

When analyzing the initial characteristics of the participants, no significant differences were observed (Table 1).

The participants showed a significant change in body weight (p = 0.006), between the decrease of 1.2 kg within the experimental group and a 0.8 kg increase in the control group. The BMI remained without significant differences. In terms of nutrient consumption, no significant differences were observed at the beginning of the study in the usual macro and micronutrient intake between the two groups (Table 2).

After 8 weeks of intervention, it was found that the participants in the experimental group showed a lower total recommended energy intake concerning the control group (p = 0,009). Both, within and inter-group consumption of proteins and carbohydrates remained stable during the period of the study. However, total fat intake (p=0,004), saturated fat (p=0,012), MUFA (p=0,010) and fatty acids n-3 (p=0,045) were reduced significantly in the experimental group. In the control group, the opposite was found, in a spontaneous way the consumption of total fat (p<0,001), saturated fat (p<0,004), MUFA (p<0,001), PUFA (p<0,001), acids n-6 (p<0,004), and cholesterol (p<0,000) increased, while the consumption of fatty acids n-3 (p<0,001) decreased.

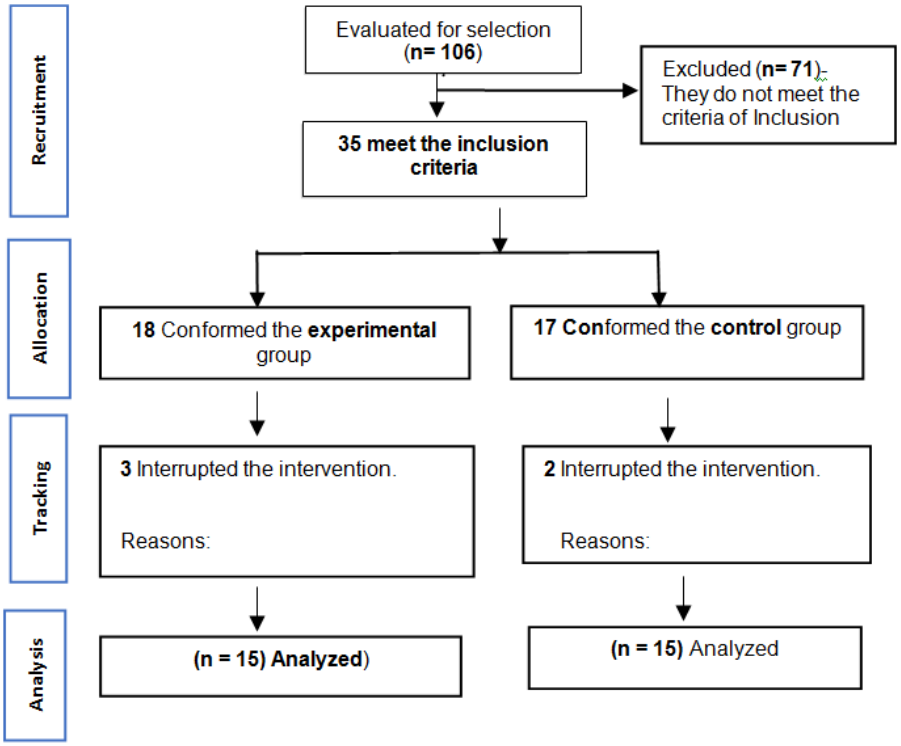

Figure 1. The two groups, flow diagram. Selection of participants (recruitment, intervention allocation, monitoring and analysis). Source: adaptation of the CONSORT Flow diagram 2010

Table 1. Baseline characteristics of study participants

Variables	Experimental group (n=15)	Control group (n=15)	Value p
	Medium/RI	Medium/RI	
Age (years)	31 (13)	29 (14)	0,755
Weight (Kg)	89,2 (15,8)	90 (21,6)	0,520
IMC (kg/m $^{2)}$	36 (7,0)	36 (6,0)	0,647
Glycemia (mg/dl)	87 (8,0)	90 (17,0)	0,183
IL-6 (pg/ml)	2,4 (1,3)	2,4 (0,87)	0,885
Hs-CRP (mg/l)	7,5 (7,7)	10,4 (18,2)	0,406
TNF-α (pg/ml)	9,9 (2,6)	10,1 (3,2)	0,678
Leptin (ng/ml)	42 (20,4)	41,5 (16,9)	0,372
Adiponectin (µg/ml)	4,6 (5,1)	4,7 (3,5)	0,740

IMC:body mass index, IL-6: Interleukin 6, hs-CRP: High-sensitivity C-reactive protein, TNF-α: Tumor necrosis factor, alpha, mg/dl: milligram over deciliter, pg/ml: Picogram about Milliliter, µg: microgram, kg/m^2: kilogram/meter Square. The data Are expressed as medium and RI: Interquartile Range. p< 0,05 Statistically significant.

Table 2. Basal characteristics of the usual dietary intake, in the 2 groups

Variables Nutritional	Experimental group (n=15)	Control group (n=15)	Value p
Kilocalories (kcal)	1947,8(1180,1)	1934,5(877,8)	0,917
Proteíns (g)	75,1(45,3)	69,8(19,0)	0,820
Total CHO (g)	236,1(171,4)	288,1(167,5)	0,604
Total Fat (g)	65,7(44,9)	60,4(27,2)	0,787
Cholesterol (mg)	228,6 (132,0)	234,1(23,50)	0,983
Saturated fat (g)	22,2(12,1)	18,2 1 (0,3)	0,384
MUFA (g)	21,8(10,9)	16,2(7,2)	0,229
PUFA (g)	13(6,6)	13,7(6,9)	0,430
n- 6 (g)	10,9(6,7)	11,7(7,8)	0,468
n- 3 (g)	0,8(0,6)	1,0(0,4)	0,296
Fiber (g)	13,9(8,8)	17,4(10,7)	0,967
Vitamin A (mg)	661,2(522,3)	430,8(289,1)	0,206
Beta carotene (µg)	1811,5(2497,6)	756,0(1266,6)	0,065
Vitamin C (mg)	63(76,1)	70,3(41,4)	0,756
Vitamin D (µg)	4(2,3)	4,6 (3,1)	0,547
Vitamin E (mg)	6,3(3,2)	3,7(2,0)	0,062
Folate (µg)	260,2(139,9)	342,1(296,0)	0,787
Sodium (mg)	3066(1696,8)	2527,2(1245,2)	0,663
Magnesium (mg)	235,2(115,4)	273(102,5)	0,917
Zinc (mg)	10,4(4,4)	7,9 (2,5)	0,237
Selenium ((µg)	56,9(25,5)	62,4(35,0)	0,983

CHO: carbohidratos, MUFA: monounsaturated fatty acids, PUFA: polyunsaturated fatty acids, n-6: fatty acids Omega 6, n-3: fatty acids Omega 3, g: gram, mg: milligrams, µg: microgramo. • The data Are expressed as medium and RI: interquartile range. p< 0,05 statistically significant.

Table 3. Comparison of baseline and final data on daily macro and micronutrient intake in both groups after 8 weeks of intervention

Nutritional Variables	Experimental group (n=15)			Control group (n=15)			Value p
	Initial	Final	Value p (Intra group)	Initial	Final	Value p (Intra Group)	(Inter groups)
Kilocalories (kcal)	1947,8(1180,1)	1585,9(533,2)	0,173	1934,5(877,8)	2018,2(475,5)	0,865	**0,009**
Proteins (g)	75,1(45,3)	63,8 1 (12,6)	0,118	69,8(19,0)	71,2(23,6)	0,865	0,096
Total CHO (g)	236,1(171,4)	231,2(104,5)	0,460	288,1(167,5)	286,1(76,5)	1,000	0,404
Total Fat (g)	65,7(44,9)	49,3(15,7)	**0,004**	60,4(27,2)	68,5(9,8)	0,293	**<0,001**
Colesterol (mg)	228,6(132,0)	180,5 6 (7,9)	0,061	234,1(123,50)	222,2(97,6)	0,532	**0,010**
Saturated fat (g)	22,2(12,1)	15(6,7)	**0,012**	18,2 (0,3)	20,1(8,2)	0,443	**0,004**
MUFA (g)	21,8(10,9)	14,7 (5,8)	**0,001**	16,2(7,2)	20(6,8)	**0,020**	**<0,001**
PUFA (g)	13(6,6)	11,4(3,7)	0,057	13,7(6,9)	15,3(2,5)	0,256	**<0,001**
n-6 (g)	10,9(6,7)	9,6(3,6)	0,551	11,7(7,8)	12,7 (3,2)	0,222	**0,004**
n-3 (g)	0,8(0,6)	0,8(0,30)	**0,045**	1,0(0,4)	1(0,10)	0,850	**<0,001**
Fiber (g)	13,9(8,8)	26,0(10,7)	**0,015**	17,4(10,7)	16,6(2,9)	0,755	**<0,001**
Vitamin A (mg)	661,2(522,3)	1540,2(666,5)	**0,001**	430,8(289,1)	532,8(375,1)	0,496	**0,001**
Betacarotene (µg)	1811,5(2497,6)	5152,3(2443,3)	**0,002**	756(1266,6)	1071,5(1267,6)	0,820	**<0,001**
Vitamin C (mg)	63(76,1)	202,8(75,7)	**0,001**	70,3(41,4)	70,7(36,0)	0,776	**<0,001**
Vitamin D (µg)	4(2,3)	4(2,3)	0,706	4,6 (3,1)	3,6(1,5)	0,609	0,832
Vitamin E (mg)	6,3(3,2)	6,8(1,5)	**0,003**	3,7(2,0)	4,3(1,7)	0,191	**0,005**
Folate (µg)	260,2(139,9)	373,8(93,5)	0,125	342,1(296,0)	343,6(95,8)	0,609	0,282
Sodium (mg)	3066 (1696,8)	2145,9(596,9)	**0,004**	2527,2(1245,2)	2932,6(1333,8)	0,820	**0,002**
Magnesium (mg)	235,2(115,4)	261,4(65,2)	0,233	273(102,5)	252,7(69,8)	0,609	0,166
Zinc (mg)	10,4(4,4)	7,6(3,3)	**0,017**	7,9 (2,5)	9,9(3,2)	0,083	**0,003**
Selenium (µg)	56,9(25,5)	64,4(18,8)	0,65	62,4(35,0)	68,9(15,9)	0,609	0,425

CHO: carbohydrates, MUFA: monounsaturated fatty acids, PUFA: polyunsaturated fatty acids, n-6: Omega-6 fatty acids, n-3: Omega 3 fatty acids, g: gram, mg: miligrams, µg: micrograms. • The data are expressed as medium and RI: Interquartile Range. • The value p Between groups: This is the result of the adjustment by the basal measurement with the ANCOVA. $p < 0.05$ statistically significant.

Table 4. Comparison of baseline and final data of anthropometric measurements and markers of inflammation in both groups after 8 weeks of intervention

Variables of anthropometry and markers of inflammation	Experimental group (n=15)			Control group (n=15)			Value p (Inter groups)	Effect size
	Initial	Final	Value p (Intra group)	Initial	Final	Value p (Intra group)		
Weight (Kg)	89,2(15,8)	88 (15,0)	0,095	90 (21,6)	90,8(20,8)	**0,012**	**0,006**	
IMC (kg/m2)	36 (7,0)	36 (7,0)	0,705	36 (6,0)	36 (6,0)	0,025	0,092	
hs-CRP (mg/l)	7,5 (7,7)	5,8 (4,8)	0,078	10,4 (18,2)	12,9 (11,5)	0,932	**0,005**	0,566
IL-6 (pg/ml)	2,4 (1,3)	2,1 (0,7)	0,061	2,4 (0,87)	3,2 (2,2)	0,256	**0,013**	0,330
Leptin (ng/ml)	42(20,4)	31,1 (16,3)	0,047	41,5 (16,9)	45,5 (18,1)	0,433	**0,004**	0,533
Adiponectin (µg/ml)	4,6 (5,1)	4,7 (5,3)	0,181	4,7 (3,5)	5,8 (3,4)	0,28	0,684	0,181
TNF-α (pg/ml)	9,9 (2,6)	11,2 (5,7)	0,402	10,1 (3,2)	9,9 (3,2)	0,730	0,513	0,089

Kg: kilograms, IMC: body mass index, IL-6: interleukin 6, hs-CRP: igh-sensitivity C-reactive protein, TNF-α: tumor necrosis factor, alpha, kg/m2: Kilogram/square meter, mg: miligram, µg: microgram, dl: deciliter, pg: picogram, ng: nanogram • Data Are expressed as medium and RI: intercuarti rangel. , • The value p Between groups is the result of the adjustment by the basal measurement with the ANCOVA. The size of the effect was measured with statistically significant Z. $p < 0.05$.

The experimental group increased their intake of fiber by 87% about the initial consumption compared to the control group that decreased by 5% during the period of study. Also, the consumption of vitamin A, beta-carotene, vitamin C, and E increased significantly in the group with the experimental diet, while sodium and zinc consumption decreased (Table 3). The intake of other nutrients such as magnesium, selenium, folate and vitamin D showed no significant differences (Table 3).

At the end of the intervention, it was evident that the group with the experimental diet significantly reduced the serum concentrations of hs-CRP, IL-6, and leptin concerning the control group (Table 4). The size of the observed effect was "big" for the changes observed in the hs-CRP and "moderate" for the ones observed in the IL-6. Meanwhile, adiponectin and TNF-α did not present any significant changes (Table 4).

4. Discussion

The results show that an intervention of 8 weeks, with a diet based on food available in the Andean Region, with foods containing anti-inflammatory properties (fiber, vitamins, polyphenols and polyunsaturated fatty acids), from fruits, vegetables, legumes, avocado, fish, dark chocolate, whole grains and peanuts reduced the serum concentrations of hs-CRP, IL-6 and leptin, which was observed in the experimental group, compared to the control group.

Additionally, the overall adherence to the diet designed was 86%, probably due, in part, to the rigorous follow-up of the participants. Moreover, the diet was carried out in real-life conditions, with food available in the region and prepared at home. Another possible explanation for the good adhesion is that participants attending bariatric

surgery are people who are more willing to start treatments that improve their health status.

Despite efforts to keep participants at a constant weight, there was a slight but significant change in body weight in the experimental group. This may be because adjusting the distribution of macronutrients can lead to a decrease in body weight [16]. The studies suggest that changes of 1.2 kg, equivalent to 1.3% of weight loss, occurred in the experimental group, and a weight gain of 0.8 kg or 0.9% in the control group, which does not induce an important metabolic response. It has been shown in studies that favorable changes in markers of inflammation have been observed with a weight loss greater than 10% of the initial body weight [16,17].

In the experimental group, an increase in the intake of fiber of 87% (26 g/day) was observed to its previous consumption. This falls within the range advocated by the WHO, which recommends an average fiber consumption of 25 g/day and maximum consumption of 35 g/day from different food sources, to prevent several chronic diseases and reduce the risk of cardiovascular diseases [2,18,19]. The decrease in the markers of inflammation found in our study could have partly been due to the fermentation of fiber in intestinal microbiota, which would produce more short-chain fatty acids and derivatives of ferulic acid which, when absorbed, would have anti-inflammatory effects [20]. These findings coincide with other studies, in which the increase in dietary fiber intake achieved changes in markers of inflammation, showing an inverse relationship between the intake of fiber and the levels of CRP, IL-6 and IL-7 [21,22,23,24].

In spite of previous evidence, other authors do not find an association between the consumption of fiber from whole grains and markers of inflammation, however they found changes in LDL, total cholesterol, insulin and postprandial glycemia [25,26,27]. The results of this would study bot probably have been better by incorporating other foods with fiber like fruits, vegetables, and legumes.

On the other hand, the women in the control group had a lower fiber consumption (16.6 g/day), due to the limited consumption of fruits, vegetables, and legumes, which could partially explain the fact that the markers of inflammation do not show changes in this group (17).

It has been shown that food acts synergistically to reduce the risk of chronic diseases [28]. In this sense, it can be said that fiber consumption alone would not explain the results of our study. However, there was also a significant increase in vitamin A (133%), beta-carotene (184%), vitamin C (222%) and vitamin E (8%) coming from other food sources in the experimental diet such as fruits, vegetables and legumes [29,30,31]. This is how the participants in the intervention diet, reached an average consumption of 4 portions of fruit (400 g)/day, with the fruits most consumed being: papaya, pineapple, mango, mandarin, red apple, orange, pear, banana, granadilla, guava, black grape, uchuva, strawberries and, in juice: blackberry, lulo and passion fruit. Additionally, there was an average intake of 300g/day of various vegetables such as red tomatoes, carrots, batavia lettuce, white onions, cucumbers, beans, celery, spinach and broccoli, which possibly contributed to the changes in CRP, IL-6 and leptin [32,33,34], due to their phenolic content and the antioxidant capacity of tropical fruits and vegetables [35,36,37,38,39], to neutralize free radicals by protecting the cells and their structures from oxidative damage [40,41,42].

Nutritional guidelines suggest that the daily consumption of around 500g of fruit and vegetables has a positive effect on health [13,43], due to their content of water, carbohydrates, minerals, vitamins y phenolic compounds [40,41]. Studies In vitro have analyzed the action of some Phytochemicals such as curcumin and resveratrol, and have shown that they are inhibitors of the activation of NF-KB in adipocytes and inflammatory gene expression, which will contribute to the reduction of low-grade inflammatory processes, such as the one presented in obesity [6,44,45].

On the other hand, evidence indicates that the inclusion of fish in the diet has a protective effect against cardiovascular diseases, because of its higher content of polyunsaturated fatty acids, in particular, EPA and DHA, which have anti-inflammatory properties [46,47,48]. A portion of blue-fish, salmon or mackerel can provide 1.5-3.5 g of fatty acids n-3, while a trout, a fish more accessible to our population, manages to offer 0.2-0.3 g of this type of fatty acids [49]. In Colombia, salmon and blue-fish are not often consumed due to their lack of availability and high cost. It is possible that, in our study, the suggested dose of 2 portions of fish per week has been insufficient, compared with clinical trials in which the consumption of 5 portions of fish, managed to reduce TNF-α, CRP and increase the adiponectin [47].

In this sense it is suggested, in later studies, to induce a higher increase of the consumption of fish in people with obesity, because, despite increasing the intake of fish in the participants of the study in the experimental group, this did not manage to increase the polyunsaturated fatty acids. On the contrary, they decreased significantly compared to the control group. The explanation could be because the experimental diet was designed to reduce total fat consumption to only 23%. However, some studies have suggested that a low-fat diet may be an important component in reducing CRP levels in women with metabolic syndrome [50]. Likewise, low-fat diets can simultaneously achieve changes in quantity and quality in the intake of macronutrients, and increased consumption of fruits and vegetables, achieving reduced markers of inflammation, as was evidenced in the present study.

In general, the experimental diet had an anti-inflammatory effect due to the changes observed in hs-CRP, IL-6, and leptin. This may be partly due to the fact that the components of the diet could contribute to generate changes in the inflammatory response, since it has been seen in intervention studies that the reduction of the markers of inflammation may be presented due to the synergistic effect of all the components of the diet and not to a particular food or nutrient [51,52].

5. Conclusions

The food-based experimental diet with anti-inflammatory nutrients, available in the region, reduced serum concentrations of CRP inflammation markers hs-CRP, IL-6, and leptin in women with obesity.

In the experimental group, this reduction was obtained without producing significant changes in the body weight

of the participants. These findings suggest that such a diet could modulate the inflammatory response and serve as a safe strategy for the management of people with obesity, especially those who fail to lose weight significantly.

Based on the achievements obtained in this research, it is suggested randomized studies are carried out with a greater number of participants and longer intervention periods, to confirm these findings. However, the results provide a basis for future studies and encourage future research in the area.

6. Study limitations

The size of the sample was small which may have generated limitations in the statistical power for some outcomes. The type I error rate could have caused multiplicity problems or multiple crossings. Another potential bias might be related to the unobserved characteristics given that it was a non-randomized study, in spite of this, both groups showed similar characteristics in the basal measurements. Due to these limitations, the results of the study should be viewed with precaution.

The strength of the study is that both the experimental group and the control initiated the study in similar basal conditions. Another aspect to highlight is the strict follow-up that was carried out with the participants through weekly, individual, face-to-face contact and telephone controls during the intervention period. Besides, participants had a good adherence to the experimental diet, which generates confidence that the results in the changes of the serum markers of inflammation of the people included in the experimental group were probably a result of the intervention. Also, the fact that the experimental diet was designed with available foods from the region probably influenced the adhesion of the participants during the experiment period.

Acknowledgments

To all the participants, to Dr. Oscar Muñoz, a bariatric surgeon, for his collaboration with the study. Also, to the laboratory of the Clinic Comfamiliar Pereira and Laboratory of Cell Physiology and Immunology of the Technological University for their support in the process of the taking of the samples.

Conflict of Interest

All authors declare that they have no conflict of interest.

Financial Support

This article was supported by Colciencias with the scholarship 727 of 2015 granted to Elcy Astudillo Muñoz, from the University of Caldas (scholarship internal. Code I-DF-007 13667), and SIEMENS laboratory. These entities did not play any role in the definition of the study design, compilation, analysis, and interpretation of the data, writing of the manuscripts or in the decision to present it for publication.

References

[1] World Health Organization. 2017, Overweight and Obesity in the Western Pacific Region An Equity Perspective. 1-68.

[2] World Health Organization. 2017, World Health Statistics 2017: Monitoring Health for The Sustainable Development Goals. World Health Organization. 116 p.

[3] Moreno, M," Definition and classification of obesity", *Rev. méd. Clín. Las Condes.*, vol. 23, no. 2, pp. 124-8, 2012.

[4] Zorzanelli, V and Folco, E., "Inflammatory Concepts of Obesity", *Int. J. Inflam.*, vol. 2011, pp.1-14, 2011.

[5] Ballantyne, C.M and Nambi, V, "Markers of inflammation and their clinical significance" *Atheroscler Suppl*., vol. 6, no. 2, pp. 21-9, 2005.

[6] García-Mediavilla, V., Crespo, I., Collado P.S., Esteller, A., Sánchez-Campos, S., Tuñón, M.J and González-Gallego, J., "The anti-inflammatory flavones quercetin and kaempferol cause inhibition of inducible nitric oxide synthase, cyclooxygenase-2 and reactive C-protein, and down-regulation of the nuclear factor kappaB pathway in Chang Liver cells", *Eur J Pharmacol*., vol. 557, no. 2-3, pp. 221-9. 2007.

[7] Freedman, M.R., King, J, and Kennedy E., "Popular Diets: A Scientific Review", *Obes Res*., vol. 9, no. Suppl 1, pp. 1-40. 2001.

[8] Greer, A., "An anti‐inflammatory diet: The next frontier in preventive medicine review", *J Am Acad Physician Assist*., vol 5, no. 2, pp. 38-47. 2012.

[9] Sears, B and Ricordi C., "Anti-inflammatory nutrition as a pharmacological approach to treat obesity", *J Obes*., vol. 2011, pp. 1-14. 2011.

[10] Urpi-Sarda, M., Casas, R., Chiva-blanch, G., Romero-Mamani, E.S., Valderas-Martínez, P., Salas-Salvadó, J., Covas, M.I., Toledo, E., Andres-La cueva, C., Llorach, R., et al, "The Mediterranean Diet Pattern and Its Main Components Are Associated with Lower Plasma Concentrations of Tumor Necrosis Factor Receptor 60 in Patients at High Risk for Cardiovascular Disease 1 – 4". *J Nutr Dis*., vol. 142, pp. 1019-25. 2012.

[11] Uusitupa, M., Hermansen, K., Savolainen, M.J., Schwab, U., Kolehmainen, M., Brader, L., Mortensen, L.S., Cloetens, L., Johansson-Persson, A., Onning, G., et al, "Effects of an isocaloric healthy Nordic diet on insulin sensitivity, lipid profile and inflammation markers in metabolic syndrome -- a randomized study (SYSDIET)", *J Intern Med*., vol. 274, no. 1, pp. 52-66, 2013.

[12] Ruth, M.R., Port, A.M., Shah, M., Bourland, A.C., Istfan, N.W., Nelson, K.P., Noyan, G and Apovian, C.M., "Consuming a hypocaloric high fat low carbohydrate diet for 12 weeks lowers C-reactive protein, and raises serum adiponectin and high density lipoprotein-cholesterol in obese subjects", *Metabolism*., vol. 62, no. 12, pp. 1779-87, 2013.

[13] Instituto Colombiano de Bienestar Familiar. *Guías Alimentarias. Basadas en alimentos para la Población Colombiana*. Bogota, 2015, Primera Edición, pp. 314.

[14] Lohman, T.G., "Skinfolds and Body Density and Their Relation to Body Fatness: A Review", *Hum Biol.*, vol. 53, no. 2, pp. 181-225. 1981.

[15] Fritz, C., Morris, P and Richler, J.J., "Effect size estimates: Current use, calculations, and interpretation"., *J Exp Psychol Gen.*, vol. 141, no. 1, pp. 2-18. 2012.

[16] Richard, C., Couture, P., Desroches, S and Lamarche, B., "Effect of the Mediterranean Diet with and Without Weight Loss on Markers of Inflammation in Men with Metabolic Syndrome", *OBESITY.*, vol. 21, no. 1, pp. 51-7. 2013.

[17] Tchernof, A., Nolan, A., Sites, C.K., Ades P.A, and Poehlman, E.T., "Weight Loss Reduces C-Reactive Protein Levels in Obese Postmenopausal Women", *Am Hear association.*, vol. 105, pp. 564-9, 2002.

[18] World Health Organization. World Health Statistics 2012 [Internet]. 2012. Available from: .http://www.who.int/gho/publications/world_health_statistics/2012/en/index.html

[19] Rubio, M., Moreno, C and Cabrerizo, Y., Guías para el tratamiento de las dislipidemias en el adulto. *Endocrinol Nutr.*, vol. 51, no. 5, pp. 254-65. 2004.

[20] Sait-Ina, M., Rasoulpour, R., Yin, L., Hubbar, A., Rosenberg, D and Charles, G., "The luminal short-chain fatty acid butyrate modulates NF-κB activity in a human colonic epithelial cell line", *Gastroenterology*., vol. 118, no. 4, pp. 724-34. 2000.

[21] Esposito, K., Palo, C. Di., Giugliano, F., Giugliano, G., Armiento M.D, and Andrea F.D., "Effect of a Mediterranean-Style Diet on Endothelial Dysfunction and Markers of Vascular Inflammation in the Metabolic Syndrome. A Randomized Trial", *JAMA.*, vol. 292, no. 12, pp. 1440-1446, 2004.

[22] King, D.E., Egan, B.M and Gueesei, M.E, "Relation of dietary fat and fiber to the elevation of C-reactive protein", *Am J Cardiol.*, vol. 92, no.11, pp. 1335-9, 2003.

[23] Ajani U.A., Ford E.S and Mokdad, A.H., "Dietary fiber and C-reactive protein: findings from national health and nutrition examination survey data". *J Nutr.*, vol. 134, no. 5, pp. 1181-5, 2004.

[24] De Mello, V.D., Schwab, U., Kolehmainen, M., Koenig, W., Siloaho, M., Poutanen, K., Mykkänen, H and Uusitupa, M., "A diet high in fatty fish, bilberries and wholegrain products improves markers of endothelial function and inflammation in individuals with impaired glucose metabolism in a randomised controlled trial: The Sysdimet study", *Diabetologia*., vol. 54, no. 11, pp. 2755-67, 2011.

[25] Jensen, M.K., Koh-Banerjee, P., Franz, M., Sampson, L., Grønbæk, and Rimm E.B., "Whole-grains, bran , and germ in relation to homocysteine and markers of glycemic control , lipids , and inflammation 1 – 3", *Am J Clin Nutr.*, vol. 83, no. 2, pp 275-83, 2006.

[26] Andersson, A., Tengblad, S., Karlstrom, B., Kamal-Eldin, A., Landberg, R., Basu, S., Aman, P and Vessby B., "Whole-Grain Foods Do Not Affect Insulin Sensitivity or Markers of Lipid Peroxidation and Inflammation in Healthy, Moderately Overweight Subjects", *J Nutr.*, vol. 137, no. 6, pp. 1401-7, 2007.

[27] Giacco, R., Costabile, G., Della-Pepa, G., Anniballi, G., Griffo, E., Mangione, A., Cipriano, P., Viscovo, D., Clemente, G., Landberg, R., et al, "A whole-grain cereal-based diet lowers postprandial plasma insulin and triglyceride levels in individuals with metabolic syndrome", *Nutr Metab Cardiovasc Dis*., vol. 24, no. 8, pp. 837-44, 2014.

[28] Jacobs, D.R and Steffen, L.M., "Nutrients, foods, and dietary patterns as exposures in research: a framework for food synergy 1 – 3" *Soc Am Nutr Clínica*., vol. 78, pp. 508–13, 2003.

[29] Richard, C., Couture, P., Desroches, S and Lamarche, B., "Effect of the Mediterranean Diet With and Without Weight Loss on Markers of Inflammation in Men With Metabolic Syndrome", *Obesity*., vol. 21, no. 1, pp. 51–7, 2012.

[30] Penny, E., Kary, H., Bonanome, A., Coval, S., Binkoski, A., Hilpert, K., Griel, A.E and Etherton, T.D., "Bioactive compounds in foods: their role in the prevention of cardiovascular disease and cancer", *Am J Med*., vol. 113, pp. 71–88, 2002.

[31] Valtueña, S., Pellegrini, N., Franzini, L., Bianchi, M. A., Ardigò, D., Del Rio, D., Piatti, P., Scazzina, F., Zavaroni, I and Brighenti, F., "Food selection based on total antioxidant capacity can modify antioxidant intake, systemic inflammation, and liver function without altering markers of oxidative stress", *Am J Clin Nutr*., vol. 87, no. 5, pp. 1290-7, 2008.

[32] Dourado, G.K and Cesar, T.B., "Investigation of cytokines, oxidative stress, metabolic, and inflammatory biomarkers after orange juice consumption by normal and overweight subjects", *Food Nutr Res.*, vol. 59, no. 1, pp. 28147, 2015.

[33] Peluso, I., Villano, D and Roberts, S., "Consumption of Mixed Fruit-juice Drink and Vitamin C Reduces Postprandial Stress Induced by a High Fat Meal in Healthy Overweight Subjects", *Curr Pharm Des*., vol. 20, no. 6, pp. 1020–4, 2015.

[34] Buscemi, S., Rosafio, G., Arcoleo, G., Mattina, A., Canino, B., Montana, M., Verga, S and Rini, G., "Effects of red-orange juice intake on endothelial function and inflammatory markers in adult subjects with increased cardiovascular risk", *Am J Clin Nutr.*, vol. 95, no. 5, pp. 1089-95, 2012.

[35] Zapata, K., Cortes, F and Rojano, B.A., "Polifenoles y Actividad Antioxidante del Fruto de Guayaba Agria (Psidium araca) Polyphenols and Antioxidant Activity of Sour Guava Fruit (Psidium araca)", *Inf Tecnológica V.*, vol. 24, no. 5, pp. 103-12, 2013.

[36] Zapata, S., Piedrahita, A.M and Rojano, B., "Capacidad atrapadora de radicales oxígeno (ORAC) y fenoles totales de frutas y hortalizas de Colombia", *Perspect en Nutr Humana.*, vol. 16, no. 1, pp. 25-36, 2014.

[37] Atala, E., Vásquez, L., Speisky, H., Lissi, E and López-Alarcón, C., "Ascorbic acid contribution to ORAC values in berry extracts: An evaluation by the ORAC-pyrogallol red methodology", *Food Chem.*, vol. 113, no. 1, pp. 331-5, 2009.

[38] Contreras-Calderón, J., Calderón-Jaime, L., Guerra-Hernández, E and García-Villanova, B., "Antioxidant capacity, phenolic content and vitamin C in pulp, peel, and seed from 24 exotic fruits from Colombia", *Food Res Int.*, vol. 44, no. 7, pp. 2047-53, 2011.

[39] Martínez, R., Torres, P., Meneses, M., Figueroa, J., Pérez-Álvarez, J and Viuda-Martos, M., "Chemical, technological and in vitro antioxidant properties of mango, guava, pineapple and passion fruit dietary fibre concentrate", *Food Chem.*, vol. 135, pp. 1520-6, 2012.

[40] Cerón, I., Higuita, J.C and Cardona, C., "Capacidad antioxidante y contenido fenólico total de tres frutas cultivadas en la región andina", *Vector*., vol. 5, p. 17-26, 2011.

[41] Watzl, B., Kulling, S.E., Möseneder, J., Barth, S.W and Bub, A., "A 4-wk intervention with high intake of carotenoid-rich vegetables and fruit reduces plasma C-reactive protein in healthy, nonsmoking men", *Am J Clin Nutr.*, vol. 82, no. 5, pp. 1052-8, 2005.

[42] Mena, M.P., Sacanella, E., Vazquez, M.A., Morales, M., Fito, M., Escoda, R., Serrano-Martınez, M., Salas-Salvadó, J., Benages, N., Casas, R., et al., "Inhibition of circulating immune cell activation: a molecular antiinflammatory effect of the Mediterranean diet", *Am J Clin Nutr*., vol. 89, no. 1, pp. 248-56, 2009.

[43] Chong, M.F., Macdonald, R and Lovegrove, J.A., "Fruit polyphenols and CVD risk: a review of human intervention studies", *Br J Nutr.*, vol. 104, no. 2010, pp. S28-39, 2017.

[44] Gonzales, A.M and Orlando, R.A., "Curcumin and resveratrol inhibit nuclear factor-kappaB-mediated cytokine expression in adipocytes", *Nutr Metab (Lond).*, vol. 5, no. 1, pp. 17, 2008.

[45] Crane, T.E., Kubota, C., West, J.L., Kroggel, M.A., Wertheim, B.C and Thomson, C.A., "Increasing the Vegetable Intake Dose Is Associated with a Rise in Plasma Carotenoids without Modifying Oxidative Stress or Inflammation in Overweight or Obese Postmenopausal Women", *J Nutr.*, vol. 141, no. 10, pp. 1827-33, 2011.

[46] Calder, P., Ahluwalia, N., Brouns, F., Buetler, T., Clement, K., Cunningham, K., Esposito, K., Jönsson, L.S., Kolb, H., Lansink, M., et al., "Dietary factors and low-grade inflammation in relation to overweight and obesity", *Br J Nutr.*, 106, 2011.

[47] Zhang, J., Wang, C., Li, L., Man, Q., Meng, L., Song, P., Frøyland, L and Du Z.Y, "Dietary inclusion of salmon, herring and pompano as oily fish reduces CVD risk markers in dyslipidemic middle-aged and elderly Chinese women", *Br J Nutr.*, vol. 108, no. 08, pp. 1455-65, 2012.

[48] Lopez-Garcia, E., Schulze, M., Manson, J.E., Meigs, J.B., Albert, C., Rifai, N., Willett, W.C and Hu F.B., "Consumption of (n-3) Fatty Acids Is Related to Plasma Biomarkers of Inflammation and Endothelial Activation in Women", *J Nutr.*, vol. 134, no. 7, pp. 1806-11, 2004.

[49] Calder, P., "Mechanisms of action of (n-3) fatty acids", *J Nutr.*, vol. 142, no. 3, pp. 592S-599S, 2012.

[50] Camhi, S.M., Stefanick, M.L., Ridker, P.M and Young, D.R., "Changes in C-Reactive Protein from Low-Fat Diet and/or Physical Activity in Men and Women with and Without Metabolic Syndrome Sarah. *Metab Clin Exp.* Vol. 59, no. 1, pp. 54-61, 2010.

[51] Jacobs, D and Tapsell, L.," Food synergy: the key to a healthy diet", *Proc Nutr Soc.*, vol. 72, no. 2, pp. 200-6, 2013.

[52] Bohn, T., Mcdougall, G.J., Alegría, A., Alminger, M., Arrigoni, E., Aura, A.M., Brito, C., Cilla, A., EL, S.N., Karakaya, S., et al., "Mind the gap-deficits in our knowledge of aspects impacting the bioavailability of phytochemicals and their metabolites-a position paper focusing on carotenoids and polyphenols", *Mol Nutr Food Res.*, vol. 59, no. 7, pp. 1307-23, 2015.