Journal of Nutrition & Food Sciences
ISSN: 2155-9600

Cano et al., J Nutr Food Sci 2014, 4:4
DOI: 10.4172/2155-9600.1000283

Research Article | Open Access

Effect of Eating *Oreochromis aureus* on Biochemical Markers in Young People

Juan Manuel Muñoz Cano[1]*, Audomaro Díaz[1], Carlos Josías Alamilla[1], Dania Caballero[2] and José Pool[3]

[1]Universidad Juárez Autónoma de Tabasco, División Académica de Ciencias de la Salud, Avenida Méndez 2838-A, CP 86150, Villahermosa, Tabasco, México
[2]Universidad Veracruzana, México
[3]Universidad Autónoma de Campeche, Agustin Melgar s/n, Buenavista, 24039 San Francisco de Campeche, Campeche, Mexico

Abstract

Background: Although non comunicable diseases have a multifactorial origin, changes in eating patterns seem to weigh more. Population groups that maintain their traditional eating patterns have a lower prevalence of these diseases.

Methods: Thirty-five students of the Universidad Autonoma de Tabasco, 22 women (62%, $\overline{X}$ 18.58 years) and 13 men (37%, $\overline{X}$ 18.76 years), were given 100 grams of *Oreochromis aureus* daily, five days a week, during eight weeks. Data on anthropometry, glucose, triglycerides, cholesterol, glycosylated hemoglobin, insulin and the HOMA-IR index were recorded before and after providing the fish.

Results: In the experimental group, significant differences were observed between the first and the second measurement of insulin (p=0.004) and of the HOMA-IR (p=0.0001). Although an increase in the amount of insulin was evident in the second value, it was not greater than the cutoff point plus one SD, according to reference values. A significant difference in after-fasting glucose values was recorded for the women, with a smaller second value (p=0.003), however this did not occur in the case of the men. A decrease in after-fasting glucose values (p=0.015) was recorded for the group that presented at least one anomaly, in contrast with the group that presented no anomaly in the initial evaluation (p=0.078). The group with no anomaly presented a slight increase in insulin (p=0.074), as well as an increase in the HOMA-IR (p=0.019), with an average in the reference intervals. A significant difference in the initial glucose (p=0.006) and HbA1c (p=0.008) values was recorded between the two groups.

Conclusions: The addition of 100 grams of *Oreochromus aureus* was accompanied by an increase in insulin values and a decrease in after-fasting glucose values, with no changes in glycosylated hemoglobin or lipids.

Keywords: Hypoinsulinemia; Type 2 diabetes mellitus; Functional food items; Tropical fish

Introduction

Non communicable diseases constitute the main health problem on a global scale, and as a group they are the main cause of death. It is estimated that they are responsible for 65% of worldwide deaths [1], a percentage that increases to 75% in Latin America [2]. Thus, type 2 diabetes mellitus, which in 1931 caused 1% of deaths in Mexico, caused 5.8% in 2001 [3], increased rapidly to 11.85% in 2007 [4] and was considered the first cause of death in 2012. Together with an increase in the prevalence of type 2 diabetes in Mexico 14% of the ≥ 20 year-old population [4] important reductions have been observed in the consumption of food items that used to be common in daily life.

The change from traditional diets to diets with greater proportions of modern industrialised food is the most important factor in explaining the pandemic [5]. In contrast, populations that maintain the habit of eating local ethnic cuisine dishes, like the Mediterranean [6,7], the Japanese [8,9] and the Mexican [10-12], have a smaller probability of developing non transmissible chronic diseases. This is the reason behind studies that analyse the protective effects of food items and dishes of traditional cuisines.

The traditional cuisine of Tabasco, in southeastern Mexico, includes fish, as the state of Tabasco is located on a flood plain subject to seasonal flooding. The two greatest rivers in Mexico are located in this region, as well as numerous lagoons inhabited by freshwater species. As a result of globalisation, many endemic species have been substituted by others that are more easily bred or have lower production costs. Such is the case of fish in Tabasco, particularly where it is difficult to cultivate wild species in farms. Tilapia fish (*Oreochromis* spp) was introduced from Africa and adapted well to the climate. The consumption of this farmed fish has increased in importance, considering feeding security. It is the main aquatic product of Tabasco, only after oysters (*Crassostrea* spp), with 3487 tons recorded in 2011 [13]. For these reasons, the purpose of this study was to evaluate the effect of eating this fish on changes in biochemical markers.

Materials and Methods

Type of study

The study was experimental, analytical, longitudinal and prospective.

Study participants

Newly arrived students of the División Académica de Ciencias de la

---

***Corresponding author:** Juan Manuel Muñoz Cano, Universidad Juárez Autónoma de Tabasco, División Académica de Ciencias de la Salud, Avenida Méndez 2838-A, CP 86150, Villahermosa, Tabasco, México, Tel: (993) 3581500; E-mail: juan.munoz@ujat.mx

Received February 04, 2014; **Accepted** June 23, 2014; **Published** June 25, 2014

Citation: Cano JMM, Díaz A, Alamilla CJ, Caballero D, Pool J (2014) Effect of Eating *Oreochromis aureus* on Biochemical Markers in Young People. J Nutr Food Sci 4: 283. doi: 10.4172/2155-9600.1000283

Citation: Cano JMM, Díaz A, Alamilla CJ, Caballero D, Pool J (2014) Effect of Eating *Oreochromis aureus* on Biochemical Markers in Young People. J Nutr Food Sci 4: 283. doi: 10.4172/2155-9600.1000283

Salud, of the Universidad Juárez Autónoma de Tabasco (DACS-UJAT) that started class the last week of August 2013.

Study design

The clinical analysis laboratory carries out studies on the newly arrived students of the UJAT as part of the enrollment process to the University. Those that enrolled in the DACS-UJAT were invited to take part in this study, and 35 students accepted. As the Bachelor's courses on campus (Medicine, Nursing, Psychology, Odontology, Nutrition) have a greater number of women, 22 were women (62%, $\bar{X}$ 18.58 years) and 13 were men (37%, $\bar{X}$ 18.76 years). The study provided 100 grams of fish daily, the five days per week that the students were on campus. The fish was bought in a local fish farm to guarantee that the product was the same species (*O. aureus*) and that it satisfied the quality controls established in the norms [14]. There was a control group with students with the same characteristics, 13 women and 6 men, who was recruitment at the same time.

The experimental phase (eight weeks) started on Tuesday 17th September and ended on Friday 8th November. The students were instructed to maintain their eating patterns and were told that the food provided was not to constitute an extra supply of calories. The fish was prepared in several ways, except fried or breaded, and fatty dressings like mayonnaise were avoided, following nutritional recommendations, as fatty acids in oils compete with those in the fish [15,16], apart from having more calories than food that is not fried and food without a dressing [17].

Anthropometry

Body mass indices were calculated following the indications established by the WHO [18] using a clinical scale (Básculas Nuevo León®, México) with capacity for 200 kg and a estadimeter. The scale was calibrated every day during the study. Body mass indice (BMI) were calculated with the mathematical expression: mass/height^2=kg/mt^2 and interpreted according to the PROY-NOM-043-SSA2-2011 for Mexico [19]. For women taller than 1.5 m and men taller than 1.6 m, a low weight is ≤ 18.49, eutrophic is 18.5 - 24.99, overweight is 25 - 29.99 and obese is ≥ 30. For women shorter than 1.49 m and men shorter than 1.59 m, a low weight is ≤ 18.49, eutrophic is 18.5 - 22.99, overweight is 23 - 24.99 and obese is ≥ 25. 9.

Extensible millimetric fiber glass Vitamex® México measuring tapes, 1.80 m long and one cm wide, were used to obtain waist and hip measurements. The ideal hip measurements for the population of this geographical area are 80 cm for women and 90 cm for men [18]. The waist-hip index was calculated by dividing the waist perimeter by that of the hip, where values of 0.85 for women and 0.90 for men were considered the cutoff point [20]. The waist-height index was calculated as waist/height, with a value below 0.5 considered desirable [18].

Biochemical parameters

Blood samples were obtained from the students by the personnel staff of the clinical analysis laboratory of the UJAT after a 12-hour fast. Sterile equipment was used and blood was collected in Vacutainer® Serum flasks (Becton Dickinson, Franklin Lakes, NJ, USA). Glucose (GPA), triglycerides (TG) and total cholesterol (TC) were recorded following a dry analytical method using the automated equipment VITROS® 250 (Ortho-Clinical Diagnostics Johnson & Johnson, Rochester, NY, USA).

Glucose was evaluated following the criteria of the "NOM-015-SSA2-2010" [21] where ≤5.5 is desirable, 5.6 - 6.9 mmol/L represents altered after-fasting glucose values (pre-diabetes) and ≥7 mmol/L indicates diabetes. Triglyceride and cholesterol levels were evaluated following the criteria of the "NOM-037-SSA2-2012" [22]. TG values ≤ 1.68 mmol/L are desirable, 1.69 - 2.25 mmol/L are borderline and ≥ 2.26 mmol/L are high. TC values ≤ 4.39 mmol/L are desirable, 4 - 4.3 are borderline low, 4.4 - 5.16 are borderline high and ≥ 5.17 are high.

Glycosylated hemoglobin

A Glycohemoglobin Pre-Fil reagent kit of StanbioLab® (Boerne, TX, USA) was used. The range of absorbance was calculated following the manufacturer's formula for each standard and sample. A conversion factor was used and the results are reported as HbA1c. Values between 4.2 and 6.2% are considered normal.

Insulin, C peptide and HOMA-IR

Insulin and C peptide were recorded with Architect 2000 equipment from Abbot Diagnostics® (Mississauga, Ontario, Ca). Insulin was considered normal at ≤ 19.3 µU/mL [23]. Resistance to insulin was determined through the HOMA-IR index. This was calculated with the following equation: (after-fasting glucose in mg/dL) (after-fasting insulin in µU/mL)/405 [24]. The cutoff value to determine resistance to insulin was 3.4, which corresponds to percentile 90 for a population of healthy under-age people [25,26].

Statistical analyses

A Statistics Package for the Social Sciences edition 15.0 (SPSS, Chicago, IL, USA) was used to process the data. Data were analysed through central tendency descriptive statistics, together with contingency tables. A related samples test was used to compare the variables of the groups, according to the biochemical markers and the sex. Pearson's correlation test was also used to compare variables among groups and between sexes. A $p \leq 0.01$ was considered statistically significant.

Ethical considerations

The study was approved by the Comité de Investigación of the División de Ciencias de la Salud, registered in the Secretaría de Investigación of the Universidad de Tabasco, number 2011-1232. The study satisfied the Helsinki Declaration of the World Medical Association, and Mexico's norm for health research Ley General de Salud en Materia de Investigación para la Salud.

Results

The data recorded before and after providing the 100 gr of *Oreochromis aureus* are presented in Table 1. One of the objectives of the study was to maintain the media of the values recorded for the anthropometric indices, and these presented no differences. This was proved by the related samples tests for the body mass, waist-hip and waist-height indices, with the first obtaining a t=-0.870 and a p=0.392. Similar data were obtained for the other two indices.

The after-fasting glucose values identified seven students with an initial glucose value ≥ 5.6 mmol/L, and only one at the end of the study, with a t=3.319 and a p=0.003. Significant differences were recorded between the first and the second measurement of insulin with a p=0.004 and a HOMA-IR, p=0.000. Although an increase in the amount of insulin was evident in the second value, it was not greater than the cutoff point plus one SD, according to reference values. An analysis of the initial and final HbA1c values showed only a decrease in the width of the standard deviation (p=0.964), with an average at the cutoff point

	Sample (n = 35)		Control (n = 19)	
	Initial	Final	Initial	Final
Weight	65.15 (14.6)	65.59 (15.94)	67.71 (14.2)	66.36 (15.1)
Waist	83.13 (11.9)	83.48 (12.12)	83.09 (12.5)	83.27 (12.9)
Hip	100.05 (10.87)	99.89 (11.57)	99.57 (11.25)	100.01 (11.32)
BMI	24.86 (4.6)	25 (5.13)	25.2 (4.9)	25 (4.76)
WHiI	0.83 (0.09)	0.84 (0.12)	0.83 (0.04)	0.83 (0.93)
WHeI	51.5 (6.86)	51.7 (7)	51.6 (7.2)	51.8 (7.7)
Glucose	93.68 (9.7)	87.05 (7.7)*	88.6 (9.9)	91.08 (9.4)
Triglycerides	125.93 (59.9)	124.31 (63.95)	124.39 (66.9)	123.28 (72.3)
Cholesterol	177.51 (48.41)	171.86 (41.27)	170.38 (50.11)	176.66 (53.8)
HbA1c	6.38 (3.24)	6.13 (1.9)	6.35 (2.4)	6.32 (2.2)
Insulin	7.7 (5.19)	10.99 (5.19)*	7.8 (5.27)	7.6 (6.88)
HOMA-IR	1.74 (1.24)	3.12 (2.06)*	1.71 (1.33)	1.72 (2.2)

Table 1: Initial and final values. BMI = body mass index, WHiI = waist-hip index, WHeI = waist-height index, HbA1c = glycosylated hemoglobin. *Significant differences in the related samples test when p ≤ 0.01.

	Women (n = 22) (SD)		Men (n = 13) (SD)	
	Initial	Final	Initial	Final
Weight	60.79 (13.23)	60.85 (14.06)	78.88 (9.63)	80.50 (12.31)
Waist	79.86 (11.22)	80.13 (11.14)	93.42 (7.5)	94 (8.98)
Hip	98.38 (11.22)	97.5 (11.10)	105.28 (8.3)	107.42 (10.3)
BMI	23.86 (4.68)	23.87 (4.98)	28 (3.21)	28.55 (4.05)
WHiI	0.81 (0.09)	0.82 (0.13)	0.88 (0.06)	0.87 (0.04)
WHeI	50.13 (6.97)	50.33 (7.05)	55.81 (4.56)	56.13 (5.16)
Glucose	93.00 (10.18)*	85.77 (7.62)*	95.87 (8.74)	91.07 (7.35)
Triglycerides	125.18 (66.8)	112.18 (64.50)	128.28 (33.40)	162.42 (47.85)
Cholesterol	177.09 (46.81)	168.31 (37.42)	178.85 (57.11)	183 (53.43)
HbA1c	6.24 (3.43)	6.28 (2.07)	6.84 (2.76)	5.68 (1.68)
Insulin	7.65 (5.5)*	10.60 (6.64)*	7.85 (4.47)	12.22 (2.47)
HOMA-IR	1.77 (1.32)*	3.23 (2.35)*	1.63 (1.07)	2.75 (0.6)

BMI = body mass index, WHiI = waist-hip index, WHeI = waist-height index, HbA1c = glycosylated hemoglobin. * = Significant differences in the related samples test when p ≤ 0.01.

Table 2: Comparison between women and men.

of 6.2%. Triglycerides and total cholesterol presented no differences.

With respect to the sex (Table 2), the after-fasting glucose values differed significantly in the women, with a decrease in the second measurement (p=0.003), in contrast with the men. Although the women's insulin values increased only slightly (p=0.029), the HOMA-IR values were significant (p=0.003). No differences were recorded for the men's insulin values (p=0.067) and the HOMA-IR (p=0.036), nor for the HbA1c (p=0.042). Pearson's correlation test indicated a significant association between the initial insulin values and the HOMA-IR in the women (p=0.0001), as well as between the final insulin values and the HOMA-IR in the men (p=0.001).

A comparison of the anthropometric indices of the students that presented anomalies and of those that did not indicated no significant differences in the media of either their pre-treatment (p=0.390) or post-treatment (p=0.186) BMI. Similar data were recorded for the other indices (Table 3). A significant difference was recorded between the initial glucose (p=0.006) and initial HbA1c (p=0.008) values of the two groups. A decrease in after-fasting glucose values (p=0.015) was recorded for the group that presented at least one anomaly, in contrast with the group that presented no anomaly in the initial evaluation (p=0.078). The group with no anomaly presented a slight increase in insulin (p=0.074), as well as an increase in the HOMA-IR (p=0.019), with an average in the reference intervals. In those that had no anomalies in the initial evaluation, the value of insulin increased slightly (p=0.027) and the HOMA-IR increased significantly (p=0.01), also with an average within the reference intervals. Pearson's test determined a significant correlation between the initial insulin and the HOMA-IR (p=0.0001) and between the final insulin and glucose (p=0.004) in those that presented at least one anomaly.

Discussion

Studies on fish diets and diabetes are controversial. Although several studies have observed a protective effect after eating fish [27-29], others have found inconsistent data [30-32] or have observed an increased risk from eating fish rich in omega 3 fatty acids [33]. As epidemiological studies analyse data for populations with a wide variety of feeding patterns, customs and geographical areas, this study was carried out to evaluate the effect of a specific fish in a tropical area, on glucose metabolism.

The selection of students according to the presence or absence of anomalies in the biochemical markers, rather than considering anthropometric indicators, was based on data related to the lack of association between body volume, or even the circumference of the waist, and the possibility of presenting anomalous glucose values [34,35]. As may be seen in Tables 2 and 3, there were no differences

	With anomalies (n = 19) (SD)		Without anomalies (n =16) (SD)	
	with anomalies	Final	Initial	Final
Weight	66.37 (15.65)	66.4 (16.75)	64.16 (14.13)	64.93 (15.77)
Waist	84.76 (11.57)	85.38 (10.68)	81.81 (12.37)	81.93 (13.3)
Hip	102.69 (9.8)	100.92 (14.75)	97.90 (11.53)	99.06 (8.61)
BMI	25.42 (4.88)	25.41 (5.29)	24.40 (4.6)	24.67 (5.14)
WHiI	0.82 (0.06)	0.85 (0.14)	0.83 (0.1)	0.82 (0.09)
WHeI	52.65 (6.14)	53.1 (5.9)	50.57 (7.4)	50.62 (7.79)
Glucose	99.46 (9.73)^{bc}	89.42 (6.33)^{b}	89 (7.1)^{c}	85.12 (8.4)
Triglycerides	170.15 (62.32)	155.46 (65.99)	90 (22.7)	99 (51.23)
Cholesterol	195.46 (64.23)	189.69 (6.33)	162.93 (23.82)	157.37 (27.11)
HbA1c	7.9 (3.01)^{c}	6.45 (2.11)	5.15 (2.96)^{c}	5.88 (1.88)
Insulin	7.96 (7.12)	11.56 (6.11)	7.49 (3.1)^{b}	10.52 (5.89)^{b}
HOMA-IR	1.96 (1.71)^{b}	3.62 (2.08)^{b}	1.56 (0.67)^{a}	2.75 (2.06)^{a}

BMI = body mass index, WHiI = waist-hip index, WHeI = waist-height index, HbA1c = glycosylated hemoglobin. ^{a} = within-group differences and ^{b} = among-group differences when $p \leq 0.01$. ^{c} = within-group differences when $p \leq 0.05$.

Table 3: Comparison among students of the sample regarding the presence of anomalies.

in the averages of the body mass, waist-hip and waist-height indices between women and men, nor between those that presented anomalies and those that did not at the first evaluation. It seems that, rather than obesity originating the anomalies, obesity occurs together with the anomalies.

The data recorded after eating *Oreochromus aureus* indicated that after-fasting glucose levels decreased and insulin increased. The relatively low insulin values recorded in this sample, both in people with anomalies in biochemical markers and in those without anomalies, increased at the end of the experiment. These differences were significant in the experimental group in general (p=0.004) and explain the decrease in the after-fasting glucose values (Table 1). However, the increase in the value of insulin was not greater than the cutoff point. This may respond to an improvement in the function of the pancreas, as hypoinsulinemia follows a decrease in the function of the beta cell and constitutes a starting point for type 2 diabetes mellitus [36].

High sustained levels of blood glucose interfere with the release of insulin, the repair of the mass of beta cells, and the translocation of membrane proteins after a silencing of genes [37]. Thus, it is possible that the low values of insulin at the beginning responded to a high consumption of sugar in food and beverages, as the HbA1c values (6.38 ± 3.24) were near or above the cutoff point in both the students with and without anomalies (Table 3) and no important changes occurred at the end of the study (p=0.73), though the standard deviation value decreased at the end (6.13 ± 1.9).

Eating fish is an aspect that does not can be masked, so it is likely producing a Hawthorne effect. Accordingly, since the subjects that are part of an experiment known change their behavior, it was possible to expect that their pattern of food consumption change. The participants could have consumed more traditional foods as part of its incorporation to the study. Traditional foods of Mesoamerica such as corn tortillas have proven metabolic effects benefices at studios in animals [38]. However, such a modification would be obvious also sample glycosylated hemoglobin values, which does not occur [39].

The main contribution of this study regards the use of a fish that is produced in fish farms in tropical regions. This is important considering that people in temperate countries eat fish with a greater content of eicosanopentaenoic fatty acid, and people in less developed tropical countries may now find available a low cost functional food item. Proof that eating *Oreochromis aureus* is associated with an improvement in glucose metabolism contributes to establishing better eating habits in order to prevent non transmissible chronic diseases associated with food and the damage they generate.

This study was limited in that it did not determine key proteins [40], the expression of genes involved in the processes of production and release of insulin, or anomalies that translate into peripheral resistance, such as the effect on glucose transporters. These are questions to be answered by experiments focused on explaining how this food item modifies glucose and insulin values.

Conclusions

Thirty-five young people were provided with 100 grams of *Oreochromus aureus*, five days per week during eight weeks. The students presented no differences between the initial and final values of body mass and glycosylated hemoglobin. This agrees with their maintaining their eating patterns during the experiment. As the students presented differences between the initial and final values of after-fasting glucose and insulin, it is very probable that eating fish was the factor that produced the changes in the glucose and insulin values.

Acknowledgements

The authors thank M.I. Juan Antonio Córdova Hernández for helping with the statistical tests, as well as Q.F.B. Alberto Hernández de la Cruz, Q.F.B. Rosa Neli Hernández Álvarez and T.L.C. Rosa Guadalupe Malpica Cuevas for helping obtain and process blood samples in the clinical analysis laboratory of the UJAT. The Programa de Mejoramiento del Profesorado para la Red de Cuerpos Académicos “Obesidad y Diabetes” supported the project “Evaluación del efecto ejercido por los ácidos grasos tipo omega 3 sobre el síndrome de resistencia a la insulina en niños con obesidad y validación de un método diagnóstico” for which this study was carried out.

References

1. Alwan A, Maclean DR, Riley LM, d’Espaignet ET, Mathers CD, et al. (2010) Monitoring and surveillance of chronic non-communicable diseases: progress and capacity in high-burden countries. Lancet 376: 1861-1868.
2. Lopez AD, Mathers CD, Ezzati M, Jamison DT, Murray CJ (2006) Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data. Lancet 367: 1747-1757.
3. Sánchez-Castillo CP, Pichardo-Ontiveros E, López-R P (2004) [The epidemiology of obesity]. Gac Med Mex 140 Suppl 2: S3-20.
4. Diabetes en números. Federación Mexicana de Diabetes.
5. Schulz LO1, Bennett PH, Ravussin E, Kidd JR, Kidd KK, et al. (2006) Effects of

traditional and western environments on prevalence of type 2 diabetes in Pima Indians in Mexico and the U.S. Diabetes Care 29: 1866-1871.

6. Buckland G, Bach-Faig A, Serra-Majem L (2008) Eficacia de la dieta mediterránea en la prevención de la obesidad. Una revisión de la bibliografía. Rev Esp Obes 6: 329-339.
7. Sofi F, Cesari F, Abbate R, Gensini GF, Casini A (2008) Adherence to Mediterranean diet and health status: meta-analysis. BMJ 337: a1344.
8. Guo H, Niu K, Monma H, Kobayashi Y, Guan L, et al. (2012) Association of Japanese dietary pattern with serum adiponectin concentration in Japanese adult men. Nutr Metab Cardiovasc Dis 22: 277-284.
9. Taniguchi A, Yamanaka-Okumura H, Nishida Y, Yamamoto H, Taketani Y, et al. (2008) Natto and viscous vegetables in a Japanese style meal suppress postprandial glucose and insulin responses. Asia Pac J Clin Nutr 17: 663-668.
10. Muñoz-Ibarra AI, Carranza-Madrigal J (2010) Perfil alimentario de una población rural de Michoacán y su asociación con obesidad, diabetes e hipertensión. Med Int Mex 26: 24-30.
11. Flores M1, Macias N, Rivera M, Lozada A, Barquera S, et al. (2010) Dietary patterns in Mexican adults are associated with risk of being overweight or obese. J Nutr 140: 1869-1873.
12. Rodríguez S (2007) Patrones dietéticos y su riesgo con sobrepeso y obesidad en mujeres del área rural del sur de México. Sal Publica Mex 49: 109-111.
13. Comisión Nacional de Acuacultura y Pesca (2011) Anuario estadístico de acuacultura y pesca. Ciudad de México: SAGARPA.
14. Sagarpa (2008) Manual de buenas prácticas de producción acuícola de tilapia para la inocuidad alimentaria.
15. Guallar-Castillón P, Rodríguez-Artalejo F, Lopez-Garcia E, León-Muñoz LM, Amiano P, et al. (2012) Consumption of fried foods and risk of coronary heart disease: Spanish cohort of the European Prospective Investigation into Cancer and Nutrition study. BMJ 344: e363.
16. Mozaffarian D, Lemaitre RN, Kuller LH, Burke GL, Tracy RP, et al. (2003) Cardiac benefits of fish consumption may depend on the type of fish meal consumed: the Cardiovascular Health Study. Circulation 107: 1372-1377.
17. Brannan RG, Mah E, Schott M, Yuan S, Casher KL, et al. (2013) Influence of ingredients that reduce oil absorption during immersion frying of battered and breaded foods. European J Lipid Sci Tech 116: 240-254.
18. World Health Organization (2011) Waist circumference and waist-hip ratio: report of a WHO expert consultation. Geneva, 8–11 December 2008. Geneva: WHO.
19. Secretaría de Salud de México (2012) Proyecto de Norma Oficial Mexicana, PROY-NOM-043-SSA2-2011, “Servicios Básicos de Salud, Promoción y Educación para la Salud en Materia Alimentaria. Criterios para Brindar Orientación.” México, DF, Diario Oficial de la Federación, mayo 28.
20. He Y, Zhai F, Ma G, Feskens EJ, Zhang J, et al. (2009) Abdominal obesity and the prevalence of diabetes and intermediate hyperglycaemia in Chinese adults. Public Health Nutr 12: 1078-1084.
21. Secretaría de Salud de México (2010) NOM-015-SSA2-2010, “Para la prevención, tratamiento y control de la diabetes mellitus”. México, DF, Diario Oficial de la Federación, noviembre 23.
22. Secretaría de Salud de México (2012) NOM-037-SSA2-2012, Para la prevención, tratamiento y control de las dislipidemias. México, DF, Diario Oficial de la Federación, julio 13.
23. Aradillas C, Tenorio E, Flores J, De la Cruz E, Calderón J, et al. (2003) Valores de referencia de insulina y lípidos en jóvenes de 16 a 18 años de edad en la ciudad de San Luis Potosí. Bioquimia 28: 9-13.
24. Keskin M, Kurtoglu S, Kendirci M, Atabek ME, Yazici C (2005) Homeostasis model assessment is more reliable than the fasting glucose/insulin ratio and quantitative insulin sensitivity check index for assessing insulin resistance among obese children and adolescents. Pediatrics 115: e500-503.
25. García Cuartero B, García Lacalle C, Jiménez Lobo C, González Vergaz A, Calvo Rey C, et al. (2007) [The HOMA and QUICKI indexes, and insulin and C-peptide levels in healthy children. Cut off points to identify metabolic syndrome in healthy children]. An Pediatr (Barc) 66: 481-490.
26. Juárez-López C, Klünder-Klünder M, Medina-Bravo P, Madrigal-Azcárate A, Mass-Díaz E, et al. (2010) Insulin resistance and its association with the components of the metabolic syndrome among obese children and adolescents. BMC Public Health 10: 318.
27. Zhang M, Picard-Deland E, Marette A (2013) Fish and Marine Omega-3 Polyunsatured Fatty Acid Consumption and Incidence of Type 2 Diabetes: A Systematic Review and Meta-Analysis. Int J Endocrinol 2013: 501015.
28. Patel PS, Forouhi NG, Kuijsten A, Schulze MB, van Woudenbergh GJ, et al. (2012) The prospective association between total and type of fish intake and type 2 diabetes in 8 European countries: EPIC-InterAct Study. Am J Clin Nutr 95: 1445-1453.
29. Karlström BE, Jarvi AE, Byberg L, Berglund LG, Vessby BO (2011) Fatty fish in the diet of patients with type 2 diabetes: comparison of the metabolic effects of foods rich in n-3 and n-6 fatty acids. Am J Clin Nutr 94: 26-33.
30. Wallin A1, Di Giuseppe D, Orsini N, Patel PS, Forouhi NG, et al. (2012) Fish consumption, dietary long-chain n-3 fatty acids, and risk of type 2 diabetes: systematic review and meta-analysis of prospective studies. Diabetes Care 35: 918-929.
31. Xun P, He K (2012) Fish Consumption and Incidence of Diabetes: meta-analysis of data from 438,000 individuals in 12 independent prospective cohorts with an average 11-year follow-up. Diabetes Care 35: 930-938.
32. Kaushik M, Mozaffarian D, Spiegelman D, Manson JE, Willett WC, et al. (2009) Long-chain omega-3 fatty acids, fish intake, and the risk of type 2 diabetes mellitus. Am J Clin Nutr 90: 613-620.
33. Djoussé L, Gaziano JM, Buring JE, Lee IM (2011) Dietary omega-3 fatty acids and fish consumption and risk of type 2 diabetes. Am J Clin Nutr 93: 143-150.
34. Muñoz Cano JM, Córdova Hernández J, Mayo H, Boldo León X (2013) [Pre-diabetes and diabetes without association with overweight or obesity in Mexican youth]. Arch Latinoam Nutr 63: 148-156.
35. Zhao X, Zhu X, Zhang H, Zhao W, Li J, et al. (2012) Prevalence of diabetes and predictions of its risks using anthropometric measures in southwest rural areas of China. BMC Public Health 12: 821.
36. Kahn SE (2003) The relative contributions of insulin resistance and beta-cell dysfunction to the pathophysiology of type 2 diabetes. Diabetologia 46: 3-19.
37. Shantikumar S, Caporali A, Emanueli C (2012) Role of microRNAs in diabetes and its cardiovascular complications. Cardiovasc Res 93: 583-593.
38. Muñoz Cano JM, Aguilar AC, Hernández JC (2013) Lipid-lowering effect of maize-based traditional Mexican food on a metabolic syndrome model in rats. Lipids Health Dis 12: 35.
39. McCambridge J, Witton J, Elbourne DR (2014) Systematic review of the Hawthorne effect: New concepts are needed to study research participation effects. J Clin Epidemiol 67: 267-277.
40. Kondo K, Morino K, Nishio Y, Kondo M, Fuke T, et al. (2010) Effects of a fish-based diet on the serum adiponectin concentration in young, non-obese, healthy Japanese subjects. J Atheroscler Thromb 17: 628-637.