Asesorías y Tutorías para la Investigación Científica en la Educación Puig-Salabarría S.C.
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RFC: ATI120618V12

Revista Dilemas Contemporáneos: Educación, Política y Valores.
http://www.dilemascontemporaneoseducacionpoliticayvalores.com/
Año: VI Número: Edición Especial Artículo no.:85 Período: Marzo, 2019.

TÍTULO: Análisis comparativo de la harina de trigo sarraceno cruda y tostada utilizada en la producción de panadería.

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RESUMEN. Se ha cubierto el problema de un número cada vez mayor de pacientes con diabetes mellitus de ambos tipos y se ha establecido el papel principal de la nutrición en la prevención y el tratamiento de esta enfermedad. Los objetivos del estudio se han formulado en base al análisis exhaustivo de la información. Se ha demostrado que la harina de trigo sarraceno permite reducir el índice glucémico de los productos terminados, independientemente de su composición. La capacidad de la harina de trigo sarraceno para reducir el índice glucémico depende del tamaño de sus partículas (granulación). Se ha demostrado científicamente que las propiedades antioxidantes de la harina de trigo sarraceno se deben a la presencia de una amplia gama de compuestos de flavonoides.

PALABRAS CLAVES: harina de trigo sarraceno, granos de trigo sarraceno, harina de trigo, diabetes mellitus.

TITLE: Comparative analysis of raw and roasted buckwheat flour used in bakery production.

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ABSTRACT: The problem of rapidly increasing number of patients with diabetes mellitus of both types has been covered and the leading role of nutrition in the prevention and treatment of this disease has been established. The objectives of the study have been formulated based on the thorough analysis of the information. It has been shown that buckwheat flour makes it possible to reduce the glycemic index of finished products, regardless of their composition. The ability of buckwheat flour to reduce the glycemic index is dependent on the size of its particles (granulation). It has been scientifically proven that the antioxidant properties of buckwheat flour are due to the presence of a wide range of flavonoid compounds.

KEY WORDS: buckwheat flour, buckwheat groats, wheat flour, rye flour, diabetes mellitus.

INTRODUCTION.

Grain products take a special place in the nutrition of Russia's population with 21 kg per capita per year. It should be noted that changes in the structure of nutrition have resulted in a decrease of bread, cereals and flour consumption. This is due, firstly, to the increase in consumption of fruits, vegetables and animal products, and secondly, to the limited production of cereals. Hence, there is a need for new technologies to produce flour from grain, traditionally used for the production of cereals,

especially buckwheat, which occupies a leading position among cereals. Currently, Russia has the largest buckwheat growing areas, and in 2017, the gross grain harvest reached 1,400 thousand tons.

The grain of buckwheat, both raw and roasted is the raw material for the industrial production of flour. Despite the fact that buckwheat flour is widely used in many bakery products (about 10–20%), its technological properties and nutritional value have not been studied sufficiently. Therefore, the advantages of buckwheat flour, in particular, its dietary value are quite relevant for bakery and confectionary.

The technological features of buckwheat were studied by many Russian and foreign scientists. Among them are G.A. Yegorov, E.M. Melnikov, G.N. Pankratov, O.N. Knyazev, T. Adachi (Japan), I. Kreft (Slovenia), S. Ikeda, K. Christa, Soral-Smietana (Czech Republic) and others.

Currently, there is an increase in the number of diabetic patients, and the fact that nutrition plays a vital role in the prevention and treatment of diabetes mellitus of both types should be borne in mind. The buckwheat contains not only complete proteins, but also flavonoids, which have a beneficial physiological effects in humans. According to the World Health Organization (WHO), at the beginning of 2016 there were 1.9 billion overweight adults in the world with 600 million with obesity, which is a nutritional chronic disease leading to cardiovascular, oncological, psychological diseases, diseases of musculoskeletal system and diabetes. Among countries with the highest number of obese people Russia is ranked 30th, and the problem becomes graver with every passing year.

The dietary characteristics of buckwheat need to be confirmed. Studies aimed at expanding the range of products containing buckwheat flour continue to be relevant.

DEVELOPMENT.

Objectives.

The purpose of our study was to describe the physico-chemical parameters of buckwheat flour obtained from raw and roasted cereals, to identify the relationship of individual indicators of finished

products with their use, to investigate biologically active compounds, such as flavonoids, and describe their impact on dietary value of bread and flour products based on buckwheat flour.

Methods.

Comparative analysis of buckwheat flour quality indicators was carried out, the influence of granulation on the surface properties of buckwheat flour was investigated, the composition of flavonoids, the effect of heat treatment on their composition were considered.

An important solution to global food problems of today (obesity, diabetes) is to replace traditional foods with more balanced ones; among them, the flour products, which are in great demand not only in Russia, but throughout the world, are particularly important.

The theory of a balanced diet originated from classical experimental natural science and one of its ideas is the creation of an ideal food and an ideal diet. So, this theory promotes the maintenance of body's vital activity based on the balance between caloric intake and output.

Dietary foods are usually made from highest grade wheat flour. But in confectionery products the wheat flour is often replaced with non-traditional types of flour and cereals, legumes, oilseeds and other vegetable raw materials. These raw materials exceed wheat flour of the highest grade in many indicators, and this leads to an increase in the nutritional value of finished products (Pankratov, 2015; Chernykh, 2012; Nikiforova, & Ignatiev, 2016).

In recent times, the buckwheat has become very popular. The grain of buckwheat can be consumed unground, crushed or ground into flour for dietary nutrition and baby food. Flour has a light beige, cream, grayish beige color and has a slightly bitter (nutty) taste. Currently, along with unground and crushed buckwheat, the flour made from raw and roasted buckwheat is largely marketed (Kaganov et al, 2008).

A comparative analysis of the chemical and mineral-vitamin composition of buckwheat flour is presented in Tables 1, 2.

Table 1. Chemical composition of buckwheat, wheat and rye flour (Skurikhin & Tutelyan, 2007).

Flour type	Proteins, %	Fats, %	Carbohydrates, %	Dietary fibres, %	Nutritional value, kcal
Wheat flour of highest quality	10,3	1,1	70,6	3,5	334
Medium rye flour	8,9	1,7	61,8	12,4	298
Roasted buckwheat flour	13,6	1,2	71,9	2,8	353
Raw buckwheat flour	12,6	3,3	57,1	2,8	310

Table 2. Mineral and vitamin composition of buckwheat flour, wheat and rye flour, mg per 100 g (Skurikhin & Tutelyan, 2007).

Flour type	Na	Ca	K	Mg	P	Fe	B_1	B_2	PP
Wheat flour of highest quality	3	18	122	16	86	1,2	0,17	0,04	1,2
Medium rye flour	2	34	350	60	189	3,5	0,35	0,13	1,0
buckwheat flour	3	42	130	48	250	4,0	0,40	0,18	3,1

Analysis of chemical composition showed that buckwheat flour has a rather high protein content. Flour from raw buckwheat has a low carbohydrate content, but contains the greatest amount of fat. The buckwheat flour has the highest content of calcium, magnesium, phosphorus, iron, as well as vitamins B1, B2, P. In turn, medium rye flour contains almost 2.5 times more potassium and its magnesium content is by 125% and 375% higher than in buckwheat and wheat flour respectively. Rye flour is higher in calcium, phosphorus, iron and B vitamins than wheat flour of the highest quality. Replacing wheat flour with buckwheat and rye flour will increase the nutritional and biological value of confectionery and bakery products.

As shown in Table 3, buckwheat proteins have a high biological value, they are the best known sources of plant proteins. It surpasses all the cereals in the content of lysine and methionine. Buckwheat proteins have a better balance in essential amino acids (valine, histidine, isoleucine, leucine, lysine, methionine, threonine, tryptophan, phenylalanine, arginine), they are easily digested, which makes buckwheat especially valuable dietary product. Lysine (11.2% of daily dose) has an antiviral effect and improves calcium absorption, normalizes the activity of the cardiovascular system; methionine (12.8% of daily dose) plays an important role in the metabolism, activates the action of hormones and enzymes; tryptophan (14.0% of daily dose) regulates the function of the endocrine apparatus of the human body. A high content of cystine and cysteine indicates a high radioprotective property of buckwheat (Gavrilova, 2008).

Table 3. Amino acid content in some foods, g per 100 g

Amino acid	Daily dose	Foodstuff				
		Chicken egg	Milk	Buckwheat	Wheat flour	Medium rye flour
Valine	3,0–4,0	0,9	0,24	0,59	0,47	0,51
Isoleucine	3,0–4,0	0,8	0,22	0,46	0,43	0,38
Leucine	4,0–6,0	1,1	0,34	0,75	0,81	0,58
Lysine	3,0–5,0	0,8	0,27	0,53	0,25	0,30
Methionine	2,0–4,0	0,4	0,09	0,32	0,15	0,12
Threonine	2,0–3,0	0,6	0,16	0,40	0,31	0,26
Tryptophan	1,0	0,2	0,05	0,18	0,10	0,11
Phenylalanine	2,0–4,0	0,7	0,17	0,59	0,50	0,50

The biological value of buckwheat proteins is comparable to other protein sources. It mainly consists of globulins (64.5%), albumin (12.5%), glutelins (8.0%).

Buckwheat proteins make up 92.3% of the nutritional value of powdered milk and 81.4% of chicken egg proteins. The content of valine is close to the milk, leucine - to the beef, and phenylalanine - to milk and beef (Table 3). In total, buckwheat proteins contain 18 amino acids. However, buckwheat proteins, unlike wheat grains, do not contain gluten, and as a result, buckwheat flour has low baking properties (Gavrilova, 2008).

Wheat, buckwheat and medium rye flours differ little in starch content. Buckwheat has about 70% of starch. It contains a high proportion of resistant starch. Buckwheat starch granules are mostly polygonal, rarely spherical, oval, and the surface of the particles is rough. These characteristics indicate that buckwheat starch can be used as a food stabilizer, thickener and as a substance to increase stickiness, which significantly affects the quality and nutritional value of the product (Gavrilova, 2008).

The content of unsaturated fatty acids in buckwheat lipids is close to 83.2%, oleic acid - 47.1%, and linoleic acid - 36.1%. They also contain linolenic acid and other polyunsaturated fatty acids. Unsaturated fatty acids regulate the level of fat in the blood and has a antioxidant effect. The buckwheat lipids include a significant amount of lecithin, which promotes the removal of cholesterol from the blood; rutin, vitamin E, essential trace elements, phytosterols and phytoestrogen. (Campbell, 2004; Guo et al, 2011; Ikeda & Yoshihisa, 1990; Jang et al, 2010).

The growing interest in buckwheat is due to flavonoids. Buckwheat flavonoids prevent the development of malignant tumors, protect the body from aging and diseases, stimulate the immune system. The high content of rutin, that cannot be worked up by human body, but comes only with food, contributes to healing of blood vessel walls, improving their elasticity and strength, thereby reducing the risk of hypertension. Regular consumption of foods containing this cereal can significantly lower blood sugar level. High-grade proteins and complex carbohydrates contained in buckwheat provide energy for a long time. (Guo et al, 2011; Antonyuk et al, 2010).

High biological activity of flavonoids is due to their antioxidant properties, very important for the human body and having a positive effect on various biological functions, for example, antimutagenic, anticancer, rejuvenating. Natural antioxidants can protect from dangerous diseases and premature aging, as evidenced by epidemiological and clinical studies. The total content of antioxidants in the most well-known cereals, legumes and grain crops is presented in table 4 (Shumniy, 1985; FU et al, 2009).

Table 4. The total content of antioxidants in dry seeds (by quercetin)

Crop	In dry grains, mg/100 g	In sprouts, mg/100 g	
		2nd day	5th day
Buckwheat	182	203	383
Mung bean	102	163	517
Chickpeas	84	190	503
Corn	42	—	—
Lentils	42	72	90
Naked oat	34	65	334
Rye	29	102	320
Wheat	24	69	275

Note: according to the data of Yashin A. and Yashin Ya.

Buckwheat has the highest content of antioxidants among cereals and grains. The recommended levels of flavonoid consumption in Russia were introduced for the first time in 2008: it is 250 mg / day for adults (including catechins - 100 mg), from 150 to 250 mg / day (including catechins from 50 to 100 mg / day) for 7–18 years old children.

Isoflavones and isoflavone glycosides, not being steroid compounds, contribute to the normalization of cholesterol metabolism, have an antioxidant effect, stabilize the calcium metabolism and hormones balance. The recommended level of consumption for adults is 50 mg a day.

It must be stressed that foreign researchers focused their attention on phenolic compounds contained in buckwheat, discussing the content of flavonoids and flavones, phenolic acids, condensed tannins, phytosterols and phagopyrin. Their amount and compositions varied in the range of 10–56 mg / 100 g depending on the type of buckwheat and its growing conditions = (Fu et al, 2009; Brunori et. al, 2010; Liang, 2009).

Six flavonoids were extracted from buckwheat groats: rutin, quercetin, orientin, vitexin, izovitexin and isoorientin. The prevalence of rutin in buckwheat was proved. Some types of buckwheat flour can be considered as a product with a high content of flavonoids, in terms of rutin, since their content is at the level of red wine and green tea. (Brunori et. al., 2010; Christa & Soral-Śmietana, 2008; Xiong et al, 2009).

Rutin is the main phenolic compound of buckwheat groats. It has been proven that raw buckwheat rutin reduces the risk of high blood pressure, counteracts the increase in capillary fragility associated with hemorrhagic disease (increased bleeding), prevents diabetes, lowers cholesterol and has antioxidant effects.

Including dishes based on buckwheat flour in the daily ration can serve as a powerful preventive measure against “the diseases of civilization”. Buckwheat-based products are recommended in the treatment of arrhythmias, neurosis, heart defects, polyarthritis, hepatitis, obesity and leukemia, low immune function (Gavrilova, 2008; Iunikhina, 2009).

Buckwheat honey has unique healing, including antioxidant, properties and, in some regions, makes the largest share of all marketable honey (with the yield of 70-100 kg per hectare).

Buckwheat processing waste can serve as a valuable raw material for feed production (Maryin & Vereshchagin, 2014). In the study of Kolpakova V.V. et al. the technology of biodegradable packaging materials from buckwheat wastes was developed (Kolpakova et al, 2008).

In recent years, raw buckwheat flour, distinguished not only by pale green color, but also by high nutrients content, has become quite popular. The flavonoid composition of raw buckwheat is richer, but its technological properties are not well-studied yet.

High grade buckwheat flour is produced in Russia in accordance with the Standard Specifications TU 9293-005-00932169-96, TU 9293-003-515-0870-2001, TU 9293-002-43175543-03, etc., and buckwheat flour for baby and children nutrition is manufactured in accordance with GOST (All-Union State Standard) 31645-2012.

Buckwheat groats contain a lot of dietary fibers, 1.5–2 times more than oats, barley and millet (Skurikhin & Tutelyan, 2007; Gavrilova, 2008; Iunikhina, 2009).

The review of scientific literature clearly shows that the improvement of technology of bakery goods production through the use of buckwheat flour, as well as the development of methods for assessing the buckwheat flour properties are relevant and have practical value.

Wheat flour of the highest grade (GOST R 52189-2003); medium rye flour (GOST R 52809-207); unground buckwheat “Don Gusto” (TU 9294-002-33150217-96); unground buckwheat "Angstrom" (TU 9294-002-33150217-96); unground buckwheat "Mistral" (GOST R 55290-2012) and "Mistral" buckwheat groats "Green" (TU 9294-003-99621687-10) were used in the course of our research.

Our study is based on the use of generally accepted and special methods of analyzing the properties of raw materials and finished products.

Sensory assessment of buckwheat flour was carried out in accordance with GOST R 31645-2012; moisture content was determined according to GOST 9404-88; grain size - according to GOST R 31645-2012; the granulometric size composition was determined using the system "GIU-1-RS"; flour surface activity was measured by Du Nouy method; and its hygroscopic properties - by tensimetric method.

The mass concentration of antioxidants calculated as quercetin equivalent was determined by the amperometric method using the TsvetIauza 01-AA instrument with a calibration curve; the content of flavonoids (in terms of rutin) was calculated by the spectrophotometric method, the group composition of flavonoids - by RP HPLC method with photometric detection.

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Discussion and Result.

Analysis of study results allows us to draw a number of conclusions regarding the organoleptic indicators of quality and chemical composition of buckwheat flour produced by various manufacturers.

1. Comparative analysis of organoleptic indicators of quality and chemical composition of buckwheat flour produced by various manufacturers.

The organoleptic characteristics and chemical composition of buckwheat flour are shown in Tables 5 and 6.

Table 5. Organoleptic indicators of buckwheat flour quality

Sample	Indicator			
	Appearance	Color	Taste	Odor
1	Homogenous bulk solid with free flowing husk particles	Dark beige	Not sour, not bitter, strongly pronounced buckwheat	Strongly pronounced buckwheat, free of foreign odors, not musty, not moldy
2		Light grey	Not sour, slightly sweet, pronounced buckwheat	Pronounced buckwheat, free of foreign odors, not musty, not moldy
3		Light beige	Not sour, not bitter, pronounced buckwheat	Pronounced buckwheat, free of foreign odors, not musty, not moldy
4		Warm grey	Not sour, not bitter, strongly pronounced buckwheat	Strongly pronounced buckwheat, free of foreign odors, not musty, not moldy
5		Light grey	Not sour, slightly sweet, slightly buckwheat	Low buckwheat, free of foreign odors, not musty, not moldy

In terms of organoleptic characteristics, samples 1–4 demonstrated differences in color from light to dark beige, from light to gray beige, as well as in shades and in intensity of buckwheat taste and smell.

Table 6. Chemical composition of buckwheat flour, in %.

Component	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Proteins	12,6	10,9	12,3	9,0	12,6
Fats	2,6	2,6	2,0	2,0	3,3
Carbohydrates	70,0	70,0	70,0	79,0	57,1

The flour samples also varied in the content of main nutrients (table 6). The amount of proteins in samples 1–4 varied from 9.0 to 12.6, carbohydrates — from 70 to 79, fats — from 2.0 to 2.6%, humidity ranged from 8.4 to 10.0%.

The granulometric composition of flour made of roasted buckwheat was assessed using screen and microscopic methods. At least 60% of all samples passed through the silk sieve No. 38. The " sieve residue" of sample 4 was 0.5% and hence complied with the requirements of GOST 31645-2012.

However, due to the influence of static electricity, the sieve method did not provide enough information to compare individual samples of flour, therefore, to determine the flour fineness, we used the microscopic method.

The comparison of surface activity and adsorption properties of roasted buckwheat flour samples showed the best indicators of sample 1 with 55–60% of particles down to 50 microns.

2. Determining the composition of buckwheat flour flavonoids and their changes during thermal processing.

Buchwheat is considered as a source of flavonoids and this fact becomes a matter of increasing public interest. Studies have shown that regular consumption of flavonoids significantly reduces the risk of cardiovascular diseases, strengthens the fragile walls of blood vessels, which has a positive effect on various biological functions, such as antimutagenic, anti-cancer, rejuvenating.

During the study, the mass concentration of antioxidants in various samples of buckwheat flour calculated as quercetin equivalent varied from 8.4 to 13.3 mg / 100 g, with the highest concentration in sample 1; in raw buckwheat flour the concentration of antioxidants was 16 mg / 100 g, exceeding their content in rye flour by 2–3 times (for different samples) (Figure 1).

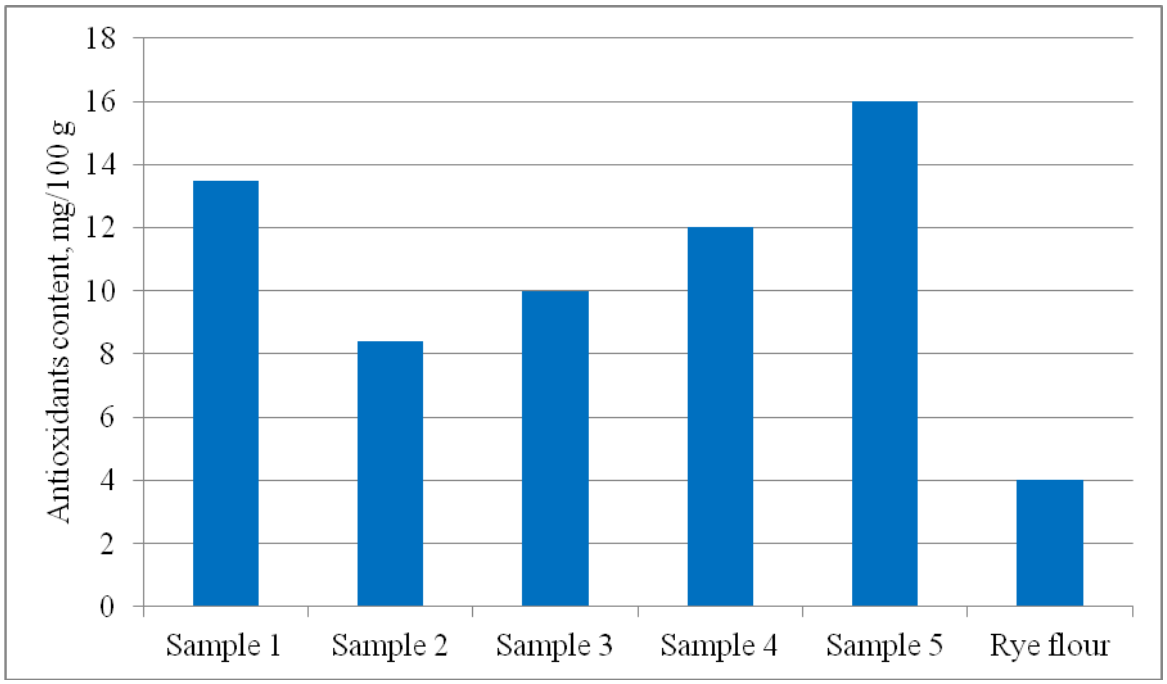

Figure 1. Mass concentration of antioxidants, calculated as quercetin equivalent.

Table 7 shows the data on the content of individual flavonoid compounds in buckwheat flour.

According to the presented data (table 7), the content of flavonoids in raw buckwheat flour is higher than in roasted buckwheat flour: catechins - by an average of 77 %; rutin - by 16.7%, the amount of flavonoids (in terms of rutin) - by 26.5%, quercetin compounds - by 25%, gallic acid - almost four times.

Table 7. The content of individual flavonoid compounds in buckwheat flour, mg / 100 g

Chemical compound	Raw buckwheat flour	Roasted buckwheat flour
Gallic acid	4	1
Amount of catechins:	257	59
• epigallocatechin	132	21
• catechin	45	1
• epicatechin	15	9
• epigallocatechine gallate	59	23
• gallocatechine gallate	5	5
• epicatechin gallate	1	следы
The amount of flavonols and flavones (in terms of rutin)	49	36
• rutine	12	10
• hyperoside	1	1
• astragalin	1	Less than 1
• quercetin	16	12
• kaempferol	5	trace
• isorhamnetin	2	1

Comparison of flavonoid contents in raw and roasted buckwheat flour confirms that a partial destruction of flavonoid compounds occurs during processing and production of roasted buckwheat (hydrothermal processing).

CONCLUSIONS.

Completed research led us to the following conclusions:

1. Buckwheat flour of different trademarks differs in sensory and physico-chemical parameters, including particle size distribution.

2. Granulometric composition is one of the decisive factors in the formation of surface characteristics of buckwheat flour. The fractions with particles size down to 50 microns should constitute 55–60% of product, as they positively influence the processing parameters of flour.

3. The composition of raw and roasted buckwheat flour flavonoids has been investigated. It has been shown that catechins predominate in the group of flavonoid compounds found in raw and roasted buckwheat flour: ~ 90% and ~ 60%, respectively; quercetin prevails among flavones and flavonols (~ 30%). It has been established that heat treatment of buckwheat reduces the flavonoids content in buckwheat flour (by an average of 16.7–77%).

Acknowledgment.

This article was written from the scientific studies supported by the Government contract 14.7404.2017 / BS "Scientific and applied bases of use of traditional and non-traditional plant raw materials (fruit, berries, grains, legumes, oilseeds, essential oil, herbs) and secondary products of their processing in manufacturing products for special nutritional, cosmetic and pharmaceutical use" awarded to FSBEI HE "MGUPP" for 2017–2019.

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RECIBIDO: 4 de febrero del 2019. **APROBADO**: 17 de febrero del 2019.