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Full Length Research Paper

Effect of processing on the content of fatty acids, tocopherols and sterols in the oils of quinoa (*Chenopodium quinoa* Willd), lupine (*Lupinus mutabilis* Sweet), amaranth (*Amaranthus caudatus* L.) and sangorache (*Amaranthus quitensis* L.)

E. Villacrés[1], G. Pástor[1,2], MB. Quelal[1/], I. Zambrano[3], SH. Morales[3]

[1/] Departamento de Nutrición y Calidad. Instituto Nacional Autónomo de Investigaciones Agropecuarias, INIAP, Fax: 3007134, e-mail: elena.villacres @ iniap.gob.ec, Quito, Ecuador
[2/] Escuela de Ingeniería Agroindustrial. Universidad Nacional de Chimborazo. 14gaby90@gmail.com, Riobamba, Ecuador
[3/] Empresa "La Fabril", izambrano@lafabril.ec.com, Manta, Ecuador

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The aim of this study was to evaluate the effect of processing on the yiel of oil extraction from quinoa grain, lupine, amaranth and sangorache and profile of fatty acids, tocopherols and sterols from oils.
Lupine presented a higher yield (19%) in oil extraction, in relation to sangorache (3,7%), quinoa (3,5 %) and amaranth (3%). The fatty acid profile revealed a low content of saturated and a higher content of unsaturated, especially linoleic acid (C18: 2), with an average of 54 % in quinoa oil and 46 % for sangorache. Oleic acid (C18: 1) predominated in lupine oil (48 %), with a lower content in amaranth oil (31%), sangorache oil (26%) and quinoa oil (24 %). Tocopherols of the form "ɣ" and "α" excelled in amaranth oil, INIAP-Alegría variety in raw state with 1138,95 ppm and lupine oil, INIAP-451 variety with 946,50 ppm, while phytosterols presented in greater proportion in the quinoa oils, INIAP-Tunkahuan and INIAP-Pata de Venado varieties with 199,0 mg/100 g oil. The main sterols were campesterol, stigmasterol, β -sitosterol, and D-5 avenasterol, which appeared in all the oils analyzed. These results suggest that Andean grains are sources of oils to meet specific health needs.

Keywords: Fatty acids, Tocopherols and Sterols, Oils of Quinoa

INTRODUCTIÓN

The lupine (*Lupinus mutabilis* Sweet), quinoa (*Chenopodium quinoa* Willd .), Amaranth (*Amaranthus caudatus* L.) and sangorache (*Amaranthus quitensis* L.) grains of Andean origin are considered strategic for the security and sovereignty Andean peoples' food in Ecuador, are part of production systems, especially in the Sierra region, these are grown in association,

Corresponding author Email: elenavillacres9@hotmail.com

Table 1. Conditions applied to the Andean grain processing

Material	Process	Description		
		time	temperature	pressure
Quinoa	Open pot cooking	20 min	91 ºC	
	expansion	20 min	180 ºC	150 psi
	Extrusion	1-2 min	130-130-180 ºC	
	toasted	2 min	196 ºC	
Lupine	hydration cooking washing	10 h 45 min 72 h	17ºC 91 ºC 17ºC	
Amaranth	soaking cooking	10 h 20 min	17ºC 91 ºC	
	popped	4,30 s	196 ºC	
	Expansion	20 min	210 ºC	120 psi
Sangorache	soaking cooking	10 h 20 min	17ºC 91 ºC	
	popped	4,30 s	196 ºC	
	Expansion	10 min	210 ºC	120 psi

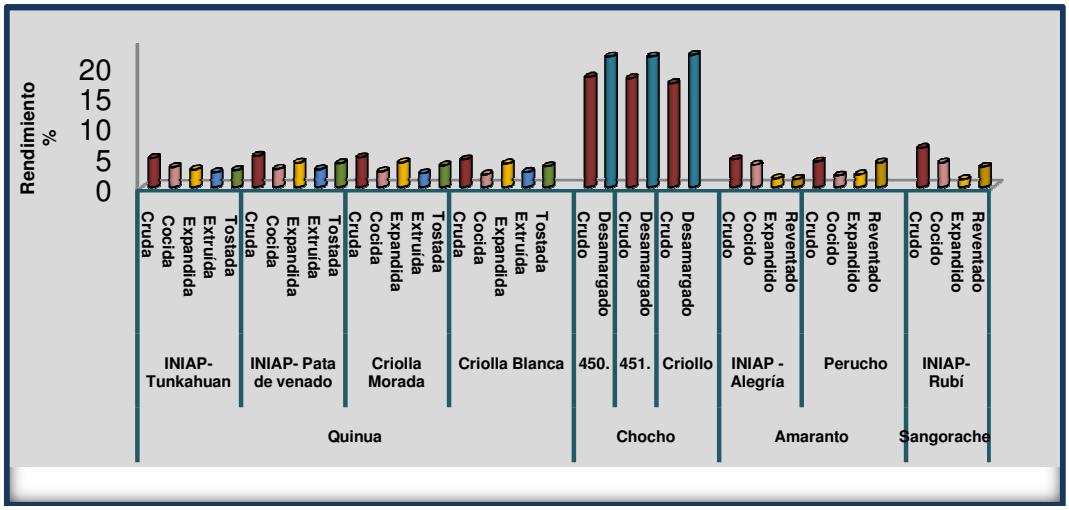

Figure 1. Yield in oil recovery, from raw and processed grains

intercropping, in monoculture or in rotation with other crops (Peralta *et al.* , 2002)

According to the National Academy of Sciences of the United States quinoa and amaranth grains are considered "golden grain" because of its high nutritional value, which is taken into account by NASA to integrate the diet of astronauts (Carrasco and Soto, 2010). In these grains, lipids account for between 4-20 % by weight and contain fatty acids, sterols and tocopherols, important to improve the health and nutritional status of the population.

Lipids are an essential part of a healthy diet in addition to confer functional properties to food very nice and hard to replace (Ramirez and Perez , 2010), are distinguished from the other macronutrients (carbohydrates and proteins) for their increased energy intake, supply 9 kcal / g to be oxidized in the body (Moreiras *et al*., 2011).

To achieve a balanced diet, 25 % of calories consumed by humans should be from fats and oils (Baudi, 2012). The Organization for Food and Agriculture and the World Health Organization (2003) recommends an intake of saturated fat less than 10%, between 15-30 % monounsaturated fat of total energy, total polyunsaturated 6-10 %. Omega 3 fatty acids must integrate the 1-2 % of the total energy (Carrero *et al.,* 2005).

From the standpoint of dietary, fats rich in saturated fatty acids are considered "bad fats" by promoting the synthesis of cholesterol and low density lipoprotein, leading to obesity and cardiovascular problems (Latin Group editors, 2008 and Ortega, 2010).

Another set of polyunsaturated fats are in this group are called "essential fatty acids" omega-6 (linoleic, C18: 2) and Omega 3 (linolenic acid, C18: 3) that offer

Table 2. Fatty acid profile (%) of oil from raw and processed (debittered) lupine

Fatty		Lupine					
		INIAP-450		INIAP-451		Criollo	
		Raw	Debittered	Raw	Debittered	Raw	Debittered
AGS	Palmitic	10,34^{a} ± 0,01	10,70^{b} ± 0,11	10,60^{a} ± 0,04	10,57^{a} ± 0,09	10,93^{a} ± 0,41	10,76^{a} ± 0,01
	Stearic	6,13^{b} ± 0,07	6,01^{a} ± 0,18	6,91^{a} ± 0,11	6,76^{a} ± 0,18	6,74^{a} ± 0,04	6,99^{a} ± 0,14
AGM	Oleic	51,13^{a} ± 0,03	45,80^{b} ± 0,37	49,07^{a} ± 0,15	48,86^{a} ± 0,41	45,16^{b} ± 0,16	46,14^{a} ± 0,38
AGP	Linoleic	27,84^{b} ± 0,22	33,46^{a} ± 0,70	29,14^{a} ± 0,23	29,15^{a} ± 0,15	31,52^{ba} ± 0,05	30,55^{b} ± 0,01
	Linolenic	2,56^{a} ± 0,01	2,99^{a} ± 0,35	2,31^{a} ± 0,03	2,23^{a} ± 0,07	2,84^{a} ± 0,01	2,53^{b} ± 0,04
Quality Indices of Fats							
AGP/AGS		1,6^{b} ±0,01	2,09^{a} ±0,03	1,66^{a} ±0,01	1,66^{a} ±0,02	1,75^{a} ±0,03	1,67^{b} ±0,01
(AGP+AGM)/AGS		4,57^{b} ±0,01	4,74^{a} ±0,09	4,26^{a} ±0,00	4,29^{a} ±0,05	4,07^{a} ±0,05	4,04^{a} ±0,02
Ratio ω-6 /ω-3		10,89^{a} ± 0,04	11,33^{a} ±1,09	12,59^{a} ±0,04	13,10^{a} ±0,47	11,11^{b} ±0,03	11,98^{a} ±0,17
Different letters indicate significant differences Average of three replicates							

Tabla 3. Fatty acid profile of the oil from four varieties of raw and processed quinoa (%)

Tunkahuan Quinoa		Raw	Cooked	Expanded	Extruded	Toast
AGS	Palmitic	10,28^{a} ± 0,22	12,40^{b} ± 0,00	9,99^{a} ± 0,01	12,32^{b} ± 0,00	10,11^{a} ± 0,09
	Stearic	0,77^{a} ± 0,17	0,89^{a} ± 0,08	0,96^{a} ±0,04	1,52^{b} ± 0,22	0,66^{a} ± 0,17
AGM	Oleic	24,66^{c} ± 0,53	30,44^{a} ± 0,00	23,15^{d} ± 0,40	27,86^{b} ± 0,03	25,18^{c} ± 0,23
AGP	Linoleic	55,45^{a} ± 0,58	45,95^{c} ± 0,00	55,02^{a} ±0,08	47,98^{b} ± 0,01	55,30^{a} ± 0,57
	Linolenic	3,25^{b} ± 0,04	3,2^{b} ± 0,00	3,25^{b} ± 0,01	3,51^{a} ± 0,01	3,34^{ab} ± 0,11
AGP/AGS		4,85^{a} ± 0,03	3,31^{c} ± 0,01	4,03^{b} ± 0,06	3,34^{c} ± 0,03	4,86^{a} ± 0,05
(AGP+AGM)/AGS		7,24^{a} ± 0,04	5,64^{c} ± 0,02	5,84^{b} ± 0,08	5,40^{d} ± 0,04	7,21^{a} ± 0,06
Pata de Venado Quinoa		**Raw**	**Cooked**	**Expanded**	**Extruded**	**Toast**
AGS	Palmitic	10,28^{ab} ±0 ,23	10,50^{b} ± 0,00	11,17^{c} ±0,01	10,13^{a} ± 0,00	10,38^{ab} ± 0,02
	Stearic	0,83^{a} ± 0,13	0,74^{a} ± 0,19	0,64^{a} ± 0,09	0,68^{b} ± 0,06	0,98^{a} ± 0,06
AGM	Oleic	27,56^{a} ± 0,15	27,7^{a} ± 0,01	22,31^{c} ± 0,00	26,93^{b} ± 0,03	21,13^{d} ± 0,00
AGP	Linoleic	51,41^{c} ± 0,26	51,39^{c} ± 0,01	55,97^{a} ± 0,30	52,14^{b} ± 0,13	52,11^{b} ± 0,01
	Linolenic	4,21^{b} ± 0,07	3,89^{d} ± 0,05	4,46^{a} ± 0,00	3,98^{cd} ± 0,02	4,06^{c} ± 0,01
*AGP/AGS		4,46^{a} ± 0,08	4,47^{a} ± 0,13	4,63^{a} ± 0,02	4,63^{a} ± 0,01	4,22^{b} ± 0,04
*(AGP+AGM)/AGS		6,94^{ab} ± 0,12	7,00^{a} ± 0,20	6,61^{b} ± 0,03	7,15^{a} ± 0,03	6,26^{c} ± 0,05
Criolla Blanca Quinoa		**Raw**	**Cooked**	**Expanded**	**Extruded**	**Toast**
AGS	palmitic	11,33^{b} ± 0,04	10,79^{a} ± 0,00	10,80^{a} ± 0,00	15,87^{d} ± 0,01	11,47^{c} ± 0,01
	Stearic	0,76^{a} ± 0,04	0,68^{a} ± 0,08	0,74^{a} ± 0,03	2,68^{b} ± 0,24	0,66^{a} ± 0,08
AGM	Oleic	21,66^{c} ± 0,00	20,82^{e} ± 0,00	25,39^{a} ±0,01	23,46^{b} ±0,01	21,00^{d} ± 0,02
AGP	Linoleic	55,67^{a} ± 0,15	56,65^{a} ± 0,19	52,54^{b} ± 0,02	52,73b ± 1,67	55,49^{a} ± 0,01
	Linolenic	4,17^{c} ±0,02	4,68^{a} ±0,06	4,03^{d} ±0,02	2,40^{e} ± 0,00	4,49^{b} ± 0,05
*AGP/AGS		4,50^{b} ± 0,10	4,89^{a} ± 0,09	4,45^{b} ± 0,05	2,89^{c} ± 0,02	4,48^{b} ± 0,11
*(AGP+AGM)/AGS		6,46^{bc} ± 0,17	6,94^{a} ± 0,12	6,83^{ab} ± 0,09	4,24^{d} ± 0,03	6,40^{c} ± 0,14
Criolla Morada Quinoa		**Raw**	**Cooked**	**Expanded**	**Extruded**	**Toast**
AGS	Palmitic	10,34^{b} ± 0,07	10,16^{a} ± 0,00	10,33^{b} ± 0,03	10,45^{b} ± 0,07	10,13^{a} ± 0,00
	Stearic	0,91^{b} ± 0,07	0,64^{a} ± 0,05	0,81^{ab} ± 0,08	0,72^{ab} ± 0,08	0,73^{ab} ± 0,08
AGM	Oleic	23,07^{a} ± 0,13	23,02^{ab} ± 0,07	22,54^{b} ± 0,32	22,92^{ab} ± 0,01	22,93^{ab} ± 0,00
AGP	Linoleic	55,60^{ab} ± 0,03	54,69^{b} ± 0,01	54,79^{b} ± 0,00	54,53^{b} ± 0,02	55,90^{ab} ± 0,01
	Linolenic	4,20^{bc} ± 0,06	4,08^{d} ± 0,01	4,24^{ab} ± 0,00	4,12^{cd} ± 0,01	4,30^{a} ± 0,02
*AGP/AGS		4,86^{bc} ± 0,01	4,93^{ab} ± 0,03	4,73^{cd} ± 0,01	4,67^{d} ± 0,05	5,08^{a} ± 0,08
*(AGP+AGM)/AGS		7,11^{b} ± 0,02	7,34^{a} ± 0,04	6,94^{bc} ± 0,03	6,80^{c} ± 0,06	7,39^{a} ±0,11
Different letters indicate significant differences Average of three replicates * Quality Indices of Fats						

Tabla 4. Ratio Omega 6 (ω6) / Omega 3 (ω3) for the oil from four quinoa varieties

Variety	Condition of the grain				
	Raw	**Cooked**	**Expanded**	**Extruded**	**Toast**
Tunkahuan	$17,06^{a} \pm 0,05$	$13,97^{b} \pm 0,02$	$16,94^{a} \pm 0,00$	$13,65^{b} \pm 0,04$	$16,57^{a} \pm 0,72$
Pata de Venado	$12,21^{c} \pm 0,25$	$13,22^{a} \pm 0,17$	$12,56^{bc} \pm 0,06$	$13,11^{a} \pm 0,11$	$12,85^{ab} \pm 0,02$
Criolla Blanca	$13,36^{b} \pm 0,04$	$12,10^{c} \pm 0,11$	$13,05^{bc} \pm 0,08$	$21,97^{a} \pm 0,67$	$12,37^{bc} \pm 0,18$
Criolla morada	$13,26^{ab} \pm 0,21$	$13,41^{a} \pm 0,02$	$12,92^{c} \pm 0,01$	$13,25^{ab} \pm 0,02$	$12,99^{bc} \pm 0,05$
Different letters indicate significant differences Average of three replicates					

Tabla 5. Fatty acid profile of amaranth oil from raw and processed sangorache (%)

Alegría Amaranth		**Raw**	**Cooked**	**Expanded**	**Popped**
AGS	**Palmitic**	$18,98^{b} \pm 0,08$	$16,26^{a} \pm 0,02$	$19,02^{b} \pm 0,02$	$19,58^{c} \pm 0,00$
	Stearic	$3,91^{b} \pm 0,07$	$2,83^{a} \pm 0,13$	$3,83^{b} \pm 0,12$	$4,15^{b} \pm 0,14$
AGM	**Oleic**	$26,16^{a} \pm 0,44$	$25,00^{b} \pm 0,00$	$25,33^{b} \pm 0,06$	$25,43^{b} \pm 0,01$
AGP	**Linoleic**	$46,06^{c} \pm 0,14$	$49,52^{a} \pm 0,00$	$46,65^{b} \pm 0,06$	$44,43^{d} \pm 0,01$
	Linolenic	$0,75^{c} \pm 0,08$	$2,14^{a} \pm 0,00$	$0,96^{c} \pm 0,03$	$1,28^{b} \pm 0,14$
ACP/AGS*		$1,38^{b} \pm 0,12$	$1,54^{a} \pm 0,02$	$1,33^{b} \pm 0,01$	$1,30^{b} \pm 0,03$
(AGP+AGM)/AGS*		$1,58^{b} \pm 0,19$	$1,71^{a} \pm 0,03$	$1,53^{b} \pm 0,02$	$1,51^{b} \pm 0,03$
(Retio ω-6 /ω-3)*		$62,37^{a} \pm 6,28$	$23,14^{c} \pm 0,05$	$48,65^{b} \pm 1,53$	$35,04^{c} \pm 3,89$
Perucho Amaranth		**Raw**	**Cooked**	**Expanded**	**Popped**
AGS	**Palmitic**	$17,87^{b} \pm 0,03$	$18,36^{c} \pm 0,30$	$18,19^{bc} \pm 0,00$	$16,97^{a} \pm 0,00$
	Stearic	$3,52^{a} \pm 0,24$	$3,86^{a} \pm 0,11$	$3,75^{a} \pm 0,15$	$5,46^{b} \pm 0,16$
AGM	**Oleic**	$36,33^{c} \pm 0,04$	$37,83^{a} \pm 0,25$	$37,23^{b} \pm 0,00$	$34,49^{d} \pm 0,04$
AGP	**Linoleic**	$37,39^{a} \pm 0,11$	$35,5^{c} \pm 0,01$	$36,50^{b} \pm 0,13$	$34,17^{d} \pm 0,02$
	Linolenic	$0,97^{a} \pm 0,03$	$0,84^{b} \pm 0,03$	$0,93^{ab} \pm 0,03$	$0,84^{b} \pm 0,03$
ACP/AGS*		$2,03^{a} \pm 0,00$	$2,06^{b} \pm 0,03$	$2,05^{b} \pm 0,01$	$2,03^{c} \pm 0,01$
(AGP+AGM)/AGS*		$2,23^{a} \pm 0,01$	$2,27^{b} \pm 0,06$	$2,25^{ab} \pm 0,01$	$2,35^{c} \pm 0,01$
(Ratio ω-6 /ω-3)*		$38,50^{a} \pm 1,36$	$42,13^{a} \pm 1,33$	$39,38^{a} \pm 1,42$	$40,51^{a} \pm 1,20$
INIAP-Rubí Sangorache		**Raw**	**Cooked**	**Expanded**	**Popped**
AGS	**Palmitic**	$18,38^{a} \pm 0,27$	$20,63^{c} \pm 0,01$	$19,77^{b} \pm 0,02$	$20,69^{c} \pm 0,41$
	Stearic	$3,88^{a} \pm 0,10$	$3,63^{a} \pm 0,12$	$3,49^{a} \pm 0,20$	$3,81^{a} \pm 0,14$
AGM	**Oleic**	$27,73^{a} \pm 0,01$	$24,41^{c} \pm 0,34$	$25,4^{b} \pm 0,07$	$25,08^{b} \pm 0,01$
AGP	**Linoleic**	$44,25^{c} \pm 0,31$	$46,65^{a} \pm 0,04$	$46,73^{a} \pm 0,01$	$45,89^{b} \pm 0,00$
	Linolenic	$0,91^{a} \pm 0,07$	$0,75^{b} \pm 0,03$	$0,95^{a} \pm 0,02$	$0,83^{a} \pm 0,00$
ACP/AGS*		$1,51^{a} \pm 0,00$	$1,18^{b} \pm 0,00$	$1,29^{a} \pm 0,01$	$1,21^{b} \pm 0,01$
(AGP+AGM)/AGS*		$1,72^{b} \pm 0,01$	$1,36^{b} \pm 0,00$	$1,46^{a} \pm 0,01$	$1,40^{c} \pm 0,01$
(Ratio ω-6/ ω-3)*		$48,82^{b} \pm 3,96$	$62,71^{a} \pm 2,78$	$49,29^{b} \pm 1,02$	$55,39^{ab} \pm 0,24$
Different letters indicate significant differences Average of three replications * Quality indices fats					

health benefits because of its important role biological to not be synthesized by the body of mammals (Carrillo *et al*, 2011) .

The intake of omega 6 helps lower cholesterol and triglyceride levels in the blood and disease prevention cardiovascular, (Carrillo *et al*., 2011).

Another group of lipid compounds present in the plant kingdom are the phytosterols or plant sterols, constituted 80% of beta-sitosterol and about 15 % for stigmasterol (Ramirez, 2010). The most concentrated source of these lipids are vegetable oils (corn, sunflower, soybean and rapeseed), which contain from 0,1 % - 0,8% , are also found in legumes (0,2%) and in smaller quantities in nuts, bread and vegetables (Palou *et al*., 2005). Unlike cholesterol, these are not absorbed in the gastrointestinal tract (Baudi, 2012) and have a hypocholesterolemic effect (Matos, 2010). Several studies show that maximum benefits are achieved through an intake of 2-3 g per day,

Tabla 6. Tocopherol content in oil from raw and processed grains

Variety		Process	γ tocopherol	α tocopherol	δ tocopherol	β tocopherol
			ppm	ppm	ppm	ppm
Lupine	INIAP-450	raw	427,00[a] ± 0,82	---	---	---
		Debittered	392,95[b] ± 0,86	---	---	---
	INAP-451	raw	946,50[a] ± 0,41	---	---	---
		Debittered	301,80[b] ± 0,16	---	---	---
	Criollo	raw	746,95[a] ± 0,86	---	---	---
		Debittered	342,55[b] ± 0,45	---	---	---
Quinoa	Tunkahuan	Raw	802,25[a] ± 0,61	773,80[a] ± 0,73	---	---
		cooked	---	---	---	---
		Expanded	130,90[c] ± 0,08	---	55,6[a] ± 0,49	---
		Extruded	65,35[d] ± 0,12	44,95[c] ± 0,20	---	---
		Toast	195,1[b] ± 0,16	368,37[b] ± 0,11	---	---
	Pata de Venado	Raw	211,45[d] ± 0,20	579,00[a] ± 0,82	---	---
		cooked	167,65[e] ± 0,29	280,50[e] ± 0,41	---	---
		Expanded	405,5[a] ± 0,41	349,60[d] ± 0,33	---	---
		Extruded	269,5[b] ± 0,41	483,50[b] ± 1,22	177,05[a] ± 0,69	---
		Toast	234,65[c] ± 0,20	428,90[c] ± 0,33	---	---
	Criolla blanca	Raw	274,85[a] ± 0,04	182,70[a] ± 0,33	---	---
		cooked	232,00[b] ± 0,82	169,90[b] ± 0,08	---	---
		Expanded	117,95[c] ± 0,04	127,65[c] ± 0,12	---	---
		Extruded	91,10[d] ± 0,00	83,05[d] ± 0,37	---	---
		Toast	---	20,95[e] ± 0,04	---	---
	Criolla morada	Raw	303,1[a] ± 0,00	518,95[b] ± 0,04	---	---
		cooked	259,05[c] ± 0,12	277,8[d] ± 0,08	---	---
		Expanded	227,1[e] ± 0,29	427,15[c] ± 0,04	---	---
		Extruded	301,5[b] ± 0,08	115,55[e] ± 0,12	---	---
		Toast	230,95[d] ± 0,04	547,95[a] ± 0,04	---	---
Amaranth	Alegria	Raw	1138,95[a] ± 0,29	91,20[a] ± 0,65	25,25[a] ± 0,61	---
		Cooked	302,75[b] ± 1,02	23,25[d] ± 0,37	---	---
		Expanded	---	49,25[b] ± 0,61	24,85[a] ± 0,12	---
		popped	---	38,90[c] ± 0,08	17,4[b] ± 0,49	---
	Perucho	raw	---	48,00[b] ± 0,24	10,9[a] ± 0,08	---
		Cooked	---	56,55[a] ± 0,12	9,05[b] ± 0,12	---
		Expanded	---	30,90[c] ± 0,08	3,00[c] ± 0,00	---
		popped	---	18,45[d] ± 0,20	---	---
Sangorache	Rubí	Raw	---	53,50[a] ± 0,41	218,00[a] ± 0,16	569,55[a] ± 0,37
		Cooked	---	---	---	---
		Expanded	---	22,07[b] ± 0,09	---	---
		popped	---	---	---	---

Different letters indicate significant differences
Average of three replicates

higher levels do not appear to produce any additional reduction effect (Hendriks, 2003 cited by Ramirez, 2010). Tocopherols are other substances that abound in vegetable fats , they make reference to vitamin E, are found especially in wheat germ oil , rice , corn , soy, egg yolks and green leafy vegetables .

MATERIALS AND METHODS

Materials

For this study were used: 4 varieties of quinoa (Tunkahuan, Pata de Venado, Crioll Blanca y Criolla morada),

Tabla 7. Phytosterol Content (mg/100 g) in oil from raw and processed grains

Phytosterols		Colestano	Squalene	Brassiscasterol	Campesterol	Stigmasterol	β-Sitosterol	D-5 Avenasterol	4,22-Sitgmastadien-3-one	Stigmast-4eno-3-one
Lupine	INIAP-450	15,00^{ab} ± 0,00	---	---	22,72^{bc} ± 0,00	23,33^{c} ± 0,01	24,62^{a} ± 0,20	24,69^{ab} ± 0,06	---	25,56^{a} ± 0,11
	INIAP-451	15,51^{a} ± 0,40	15,77^{a} ± 0,00	---	22,66^{c} ± 0,00	23,30^{c} ± 0,04	24,25^{b} ± 0,04	24,53^{ab} ± 0,18	---	25,47^{a} ± 0,10
	Criollo	15,01^{ab} ± 0,01	---	---	22,67^{c} ±0,02	23,48^{b} ± 0,05	24,33^{ab} ± 0,02	24,90^{ab} ± 0,01	25,16^{ab} ± 0,01	25,55^{a} ± 0,11
Quinoa	Tunkahuan	15,12^{ab} ± 0,00	15,68^{b} ± 0,03	22,23^{b} ± 0,07	22,76^{abc} ± 0,01	23,49^{ab} ± 0,01	24,45^{ab} ± 0,11	24,95^{a} ± 0,04	25,14^{b} ± 0,00	25,52^{a} ± 0,09
	Pata de Venado	15,13^{ab} ± 0,01	15,63^{c} ± 0,01	22,29^{ab} ± 0,01	22,75^{bc} ± 0,01	23,45^{b} ± 0,01	24,58^{a} ± 0,04	24,94^{a} ± 0,05	25,10^{b} ± 0,00	25,46^{a} ± 0,12
	Criolla blanca	15,09^{ab} ± 0,00	15,61^{c} ± 0,00	22,35^{a} ± 0,01	22,75^{bc} ±0,00	23,46^{b} ± 0,02	24,62^{a} ± 0,08	24,38^{b} ± 0,39	25,12^{b} ± 0,01	---
	Criolla morada	14,92^{b} ± 0,09	15,59^{c} ± 0,02	22,28^{ab} ± 0,04	22,83^{ab} ± 0,11	23,48^{b} ± 0,05	24,38^{ab} ± 0,05	24,66^{ab} ± 0,11	25,25^{ab} ± 0,17	---
Amaranth	Alegria	15,34^{ab} ± 0,23	---	---	22,73^{bc} ± 0,02	23,45^{b} ± 0,04	24,41^{ab} ± 0,04	25,67^{ab} ± 0,11	25,33^{a} ± 0,01	25,49^{a} ± 0,09
	Perucho	15,20^{ab} ± 0,04	---	---	22,89^{a} ± 0,00	23,59^{a} ± 0,04	24,61^{a} ± 0,05	24,80^{ab} ± 0,10	25,08^{b} ± 0,01	25,49^{a} ± 0,13
Sangorache INIAP-Rubí		15,05^{ab} ± 0,04	15,68^{b} ± 0,00	22,23^{b} ± 0,00	22,64^{c} ± 0,01	23,26^{c} ± 0,00	24,33^{ab} ± 0,07	---	---	---

Different letters indicate significant differences
Average of three replicates

,3 varieties of Lupine (INIAP-450, INIAP-451, Criollo), 2 amaranth varieties (INIAP-ALEGRÍA and Perucho) and a sangorache variety (INIAP-Rubí).

Methods

Yield in obtaining oil: It was determined by gravimetric

Fatty acid profile: was performed by gas chromatography following the method of the American Oil Chemestry Society, AOCS Official Method Ce 1h-05.

Sterol: was determined by gas chromatography according to AOCS Recommended Practice-Ce 3-74.

Tocopherols: High performance liquid chromatography (HPLC), according to the Official AOCS, Method Ce 8-89.

Methodology

Clean and free of impurities grains were divided into two portions. A for characterization of the fat from raw grains and other for process, this was made under the conditions specified in Table 1. Water cooked grains were dried in a forced air oven at 50 ° C for 8 hours, then were ground in an electric mill at 1600 rpm, portions thereof were placed on filter paper and macerated for 12 hours in hexane. After this time, the solvent was evaporated and the recovered oil on a rotary evaporator to 60^{o}C.

Statistical analysis

The reported values for the different parameters analyzed were processed in the program InfoStat.

RESULTS AND DISCUSSION

Oil Yield recovery

The higher yield in the oil extraction was obtained from lupine, both in the raw state as debittered, relative to the other species with lower yields, as shown in Figure 1. These results are attributable to the higher content of lipids naturally present in the species *Lupinus*, recovery was increased in the processed grain (debittered) due to the lipid concentration at the expense of the decrease of other nutrients such as starch, sugars and some minerals present in grain.

The opposite effect was determined in the quinoa, amaranth and sangorache whose performance in the recovery of oil decreased relative to raw grains, applying roasting processes, extrusion and

expanded. Possibly due to the high temperatures encountered in these processes which lead to changes in the chemical composition and properties of the grains (Dobraszczyk *et al*., 2008).

Fatty Acid Profile

Lupine oil obtained from both raw and debittered grain, showed a higher content of oleic acid (48%) (Table 2) compared with other vegetable oils (soybean and sunflower) having an average of 22 % (Navarrete, 2010) , this characteristic makes it suitable for frying processes , due to the better stability of monounsaturated fats . Also the highest content of this fatty acid in the lupine oil may aid in the prevention of certain cardiovascular and liver disease as well as in the maintenance of health (Botanical, 2012; Navarrete, 2010). In INIAP-450 variety, oleic acid, showed a slight decrease by debittering effect of the process, (Tukey 5%), while the INIAP-451 variety no statistical differences between oleic acid from raw grain and processed. In the native variety, the content of this acid was higher in debittered grain with respect to the raw grain.

In the lupine, polyunsaturated fatty acids (Omega 3 and 6), together accounted for 33 % of the total oil, 30 % occurred as linoleic acid and 3% as linolenic acid. Result important for nutrition and human health, as these essential fatty acids help the normal development of the fetus and infant, and could help in reducing the risk of cardiovascular disease (Editors Latino Group, 2008). In general, the proportion of these fatty acids did not vary significantly by debittering effect of the grain.

With regard to the saturated fatty acids, lupine was moderate palmitic acid, on average 10,65%, followed by 6,61% stearic acid. The content of these fatty acids did not change significantly as a result of the grain debittering in INIAP-451 and Criolla varieties, but not in INIAP-450 variety had a higher palmitic acid content in the grain debittered (10,70%) with respect to the raw grain, the opposite effect was observed in stearic acid.

Regarding the quality of fat, polyunsaturated fatty acids ratio / saturated fatty acids (GP / AGS) shows that lupine oil is of good quality as the value exceeds 0,5, established at least for edible oils (Moreiras, 2011). Similarly the ratio (PUFA + MUFA) / SFA exceeded the minimum level (2.0) to be met an edible oil. Another index that helped to determine the quality of oil is the ratio Omega 6/omega 3 ratio, which must be below 10:1 for a good quality fat. The nearest oil this ratio both in its raw state as debittering was from INIAP-450 variety, which presented a 11:1 ratio. These findings contributed the highest content of mono and polyunsaturated fatty acids and a lower content of saturated fatty acids.

The values in Table 3, show that in the oil extracted from quinoa grain raw and processed, predominant mono and polyunsaturated fatty acids. The oleic acid content ranged from 21,66% for oil from Criolla blanca variety to 27,56 % for oil from INIAP-Pata de Venado, in raw state. In the processed grain oil, the range of variation was from 20,82 to 30,44 % for INIAP-Tunkahuan and criolla blanca cooked grain. In general, oleic acid positive changes experienced due to the firing and expanded in the case of the "Criolla blanca" variety that reflected an increase of the concentration of oleic acid, while extrusion processes and toasted grain caused a slight decrease in oleic acid, relative to raw grain. Another fatty acid found in significant concentration in quinoa oil was linoleic acid concentration which ranged from 51,41 to 55,67 % in the raw grain oil, while the oil from the cooked grain, variation range was 45,95 to 56,65 %, corresponding to Tunkahuan y Criolla blanca varieties, respectively. These values are similar to the unrefined soybean oil (55.60%) and higher than those recorded for lupine oil (30,28 %), amaranth (42%) and sangorache (46 %), however did not exceed the value reported for sunflower oil (62,8 %). The average values of linoleic acid (54%) and linolenic acid (4%) in quinoa oil were similar to those determined by Rubio, (2005) in two quinoa ecotypes. The average concentration of linolenic acid in quinoa oil was lower than that cited for refined oil (5,18 %) and raw oil (6,49 %) of soybean, but exceeded the average value of lupine, amaranth and sangorache oils. The various process conditions, in some varieties helped increase the content of linoleic acid, while in others caused a decrease, with relation to grain raw oil. Such changes occurred in greater proportion in INIAP- Tunkahuan variety, whose content was significantly reduced by cooking processes and extruded (Tukey 5%), but not varied with the expanded and roasting processes. In the linolenic acid changes were lower as a result of processing, in three of the varieties tested, except for the Criolla blanca variety, whose content was increased by the effect of cooking and toasting with a sudden decrease with expansion and extruded (Table 4).

Quinoa oil in raw state presented moderate amounts of palmitic acid (C16: 0), 11% in average and a low content of stearic acid (C18: 0) with 0,90%. Processing affected to varying degrees above the concentration of fatty acids , as reflected in the ratio PUFA / SFA, in some cases positively and in others negatively, and the Criolla blanca variety of quinoa, whose value PUFA / SFA decreased due to the extrusion from the raw grain 4,50 to 2,89 in the extrudate .

The ratio (AGP + AGM) / SFA, in most varieties not change significantly (Tukey 5%) by effect of processing, except for the Criolla blanca variety, whose value decreased from 6,94 to 4,24 by the effect of extrusion , however is greater than the minimum level established for edible fats. The balance between ω -6 fatty acids and ω - 3 is important in the diet to achieve health benefits. It has been suggested that the relative amounts of linoleic

acid and α -linolenic acid contained in the feed must be below 10:1 (FAO, 1997). The oil of the Criolla blanca variety cooked state, is the most approached this share.

The saturated fatty acid content in amaranth and sangorache oils the both raw and processed, exceeded the values recorded for lupine and quinoa oils. Palmitic acid reached an average 18,2% in amaranth oil and 20% in sangorache oil while stearic acid averaged 4% in the oil coming from the two grains. Cooking caused an increase in palmitic and stearic acids in Perucho amaranth variety, in relation to raw grain, similar result occurred in oil of INIAP-Alegria popped and sangorache. A firing action contrary occurred in the oil of INIAP-Alegria and oil of Perucho variety. Stearic acid experienced similar variations by processing effect .

It determined a higher content of oleic acid in Perucho amaranth variety, with an average of 36,33% in raw oil and 37,83 % in cooked grain oil. Sangorache while the content fluctuated between 24,41% to grain cooked oil and 27,73% to grain raw oil. The different process conditions did not significantly affect oleic acid content of INIAP-Alegria amaranth and INIAP-Ruby sangorache (Tukey 5%), but not, Perucho amaranth, in which oleic acid decreased from 36,33 to 34,49 % due to the popped. In relation to linoleic acid, Perucho variety amaranth showed a smaller range of variation (from 34,17 to 37,39 %) while in the INIAP-Alegria variety, the average ranged from 44,43 % for popped grain oil to 49,52 % for the cooked grain. The different process conditions significantly affected the proportion of linoleic acid of Perucho amaranth variety whose content decreased from 37,39 % in the raw grain to 34,17 % in the popped grain. Linolenic acid with respect to both amaranth as sangorache had a lower content, relative to the lupine and quinoa. The various process conditions, did not significantly affect the content of this fatty acid in Perucho amaranth and the sangorache, while INIAP-Alegria amaranth variety, firing induced an increase from 0,75 to 2,14% (Table 5) .

The above changes had an impact on an increase or decrease of the quality indices PUFA / SFA and (PUFA + MUFA) / SFA. Both as in sangorache as amaranth, is considered negative high ratio (ω6) / (ω3), the same ranging between 23,14 to INIAP-Alegría oil from cooked grain, to 62,20 to oil from sangorache cooked grain. This is because recent research shows that increased intake of ω -6, promotes an increase in the incidence of lung, prostate and colon (Ramirez *et al*., 2010; Piñeiro *et al*., 2013; Carrillo, 2011).

In general, lupine, quinoa, amaranth and sangorache oil had a low content of saturated fatty acids, with the greatest presence of unsaturated fatty acids in concentrations of 81 %, 87%, 76% and 74%, respectively. It was determined that the total content of unsaturated fatty acids in quinoa and lupine oils, is like soybean oil (84%) and olive oil (86 %), which can help maintain health as linoleic acid reducing levels of cholesterol and LDL in serum, while the oleic acid has a neutral behavior with respect to LDL, but moderately increases the level of high density lipoproteins (HDL) (FAO, 1997).

Tocopherol Content

Vitamin E, exist in four forms (α , β , γ , δ), all belonging to the group of tocopherols. These contain double bonds in its chemical structure, so that function in the body as natural antioxidants, protecting substances such as unsaturated fatty acids, carotenes and ascorbic acid (Barrie, 2012).

Oils Andean grains raw, presented significant concentrations of ɣ and α - tocopherol; raw oil amaranth grain, INIAP – Alegria variety, showed the highest content of ɣ - tocopherol (1138,95 ppm), followed by the lupine, INIAP -451 variety with 946,50 ppm and the oil extracted from the grain quinoa, INIAP-Tunkahuan variety with 802,25 ppm. Sangorache oil thus not detected tocopherol however, α-tocopherol was introduced at a concentration of 53,5 ppm in the raw grain oil and 22,7 ppm in the expanded grain oil. These results are important, considering that tocopherols are the main body liposoluble antioxidants found in the lipoproteins, especially LDL, as part of cell membranes and improving protection against free radical attack. Current data on antioxidants, tocopherols specifically suggest a protective effect against coronary heart disease in humans. A high intake of tocopherols is associated with a reduced risk of heart disease (FAO, 1997).

The α - tocopherol, which is the most important form of vitamin E, having increased biological activity (Badui, 2012), are found in greater amounts in the INIAP-Tunkahuan variety raw oil of quinoa with 774 ppm, followed INIAP-Pata de Venado variety, in roasted (729 ppm) and extruded (683 ppm) state, these values are higher than those reported for olive and soybean oils with 529,1 and 93,8 ppm, respectively, without however, did not exceed the value of 812,4 ppm, reported for sunflower oil (Navarrete,2010). In Perucho amaranth variety, popped state and quinoa, variety " Criolla blanca" toast state, contents were lower (18,45 and 21 ppm) .

The ability of tocopherols as antioxidants is higher in the fractions that have no biological activity (β , ɣ , δ) , they act as protective agents against degenerative diseases such as coronary heart disease (Charnock, 1995, quoted by Soyago *et al*., 2007), neuronal degeneration and appearance of tumors (Albanes *et al*. , 1997, quoted by Soyago *et al*., 2007 ; Dabrowska and Moya, 2009). As stated above, the raw oils of lNIAP-Alegria amaranth, INIAP-451 lupine and INIAP-Tunkahuan quinoa grains with 1138,95; 946,50 and

802,25 ppm of γ-tocopherol, like sangorache raw oil with 569,55 ppm β -tocopherol, 218 ppm δ -tocopherol, would present a higher antioxidant activity with respect to the other materials in this study.

The results in Table 6 also show that the process conditions applied in the processing of grain, cause losses in the different fractions of tocopherol, possibly due to oxidation of vitamin E, which leads to the formation of a series of compounds and substances including dihydroxy quinones (Badui, 2012). Therefore, tocopherol concentrations in various forms, are smaller and even disappear processed grains, with respect to their sources.

Phytosterol Contents

These compounds are plant sterols that are found only in plants that have a structure similar to cholesterol or shape. Unlike the latter, they are synthesized or formed by the body and are poorly absorbed by the gut, interfere with cholesterol absorption by structural competition. The difference in structure between the side chain of phytosterols and phytostanols in cholesterol chain is the factor responsible for the hypocholesterolemic effects attributed to both types of plant sterols and its low absorption in the intestine (Ramirez and Perez, 2010).

The cholestane, campestrol, stigmasterol and β-sitosterol, were presented in the oils of all species and varieties of this study, from raw grains, while squalene was not detected in "INIAP-450 " and Criollo lupine varieties and the two amaranth varieties. In raw grains oil , there was the following averages: β - sitosterol 24,46, stigmasterol 23,43; brassiscasterol 23,00, campesterol 22,00; cholestane 15,00 and squalene 16,00 mg/100 g oil. Total sterols, determined in this study are lower than those reported by Kelly *et al*., (2007), for the oils of corn, soya and sunflower, however, exceed the average reported for almond and peanut seeds with 143 and 141 mg/100 g oil, respectively. Based on these results, we can infer that Andean grains can be considered as nutraceuticals able to help reduce cholesterol in humans, and that a daily intake of 1,3 grams is enough to lower blood cholesterol by about 10 %, as long as consumption is accompanied by a healthy diet (Benavides, 2012).

CONCLUSION

The highest yield in oil extraction, was obtained from debittered lupine, "Criollo" variety with 21,63%, followed by INIAP-451 and INIAP-450 varieties, with 21,36%. A lower extraction yield was obtained from quinoa, amaranth and sangorache grains, both raw and processed.

The fatty acid profile showed that lupine, quinoa, amaranth and sangorache oils are rich in linoleic acid, with average values of 30,28% in the lupine, 56,4% in quinoa, 41 % in amaranth and 46% in sangorache. For linolenic acid was determined the following average values: 2,58% lupine, 3,90% quinoa, 1,1 % amaranth and 0,9 % sangorache.

Quality indices showed that fat lupine oils, quinoa and amaranth are suitable for human consumption. Not so, sangorache oil, which presented a high ratio ω6/ω3.

Ɣ tocopherol forms and α, predominated in the oils studied, the ɣ-tocopherol prevailed INIAP-Joy amaranth, green state with 1138.95 ppm and the variety of pussy INIAP-451 with 946.50 ppm, while that the α-tocopherol, dominated quinoa varieties. Results showing the potential of Andean grains as antioxidants, which can help in the prevention of certain diseases.

Andean grains have moderate content of phytosterols, but they are a source for preparing enriched supplements aimed at reducing LDL cholesterol levels and combat oxidative stress.

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