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Effect of parching process on nutritional and physical characteristics of quinoa

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Abstract
Pseudo-cereals have considerable scope to be utilized as health food, because it has better nutritional quality as compared to some other cereals in many respects and studies on this line are progressing. However, quinoa is underutilized because of lack of suitable processing technology. The processed quinoa obtained as outcome of the present study will be useful in developing low cost health foods by certain processing techniques such as parching can be easily adopted at cottage and even at household level. Objective of the study was assessment of effects of parching on nutritional and physical characteristics of quinoa. The results showed that acceptable processed products could be produced from quinoa by optimization of parching method. Parched quinoa improved nutrition in terms of proteins, carbohydrates, *In-vitro* protein digestibility, *In-vitro* starch digestibility and good sensory acceptability. Based on the optimization of processing method, parched quinoa which was parched at 160°C for 30 sec were found to be most acceptable product. All the processed products showed improvement in water absorption capacity, expansion volume and bulk density which was useful for further formulation and product development. Thus, in the light of the scientific data it may be concluded that nutritional bioavailability and digestibility of quinoa could be improved by reducing its bitter content and in this regards the processing method contribute to enhancing utilization of quinoa based products.

Keywords: Pseudo-cereals, quinoa, parching, protein digestibility, low cost health foods

Introduction
Quinoa (*Chenopodium quinoa willd*), as an annual herbaceous flowering plant belonging to Chenopodiaceae family. Quinoa is a gluten-free pseudo-cereal that contains a high amount of fibre, high biological-value proteins, essential fatty acids (ω-3 and ω-6), vitamins and minerals (Stikic *et al.* 2012; James 2009) [23, 11]. Due to its rich protein content and incredible balance of essential amino acids, it has been consumed by people as a holy plant (Jancurova 2009, Maradini Filho *et al*. 2015) [12, 15]. Moreover, the amounts of calcium, magnesium, iron, and phosphorus (especially calcium and iron) are significantly higher than in most other cereals (Bhargava *et al.* 2006; Repo-Carrasco *et al.* 2003) [5, 20]. Parched grain is whole grain that has been cooked by dry roasting. It is an ancient foodstuff and thought to be one of the earliest ways in which gathers ate grains. Parched grain is a compact, nutritious, energy dense food that is easily transported and consumed. Parching quinoa would seem to have considerable potential for home and large scale growers. In parching process, seeds are lightly toasted to keep them out from sprouting or germination. The extensive utilization of quinoa could be increased, because the grains are highly nutritious having exceptional protein quality and a wide range of vitamins and minerals. So these should be taken into account when planning novel products based on this grain. Hence the present study was carried out to know the effect of processing on its nutritional characteristics.

Material and Methods
Good quality of quinoa were collected and cleaned properly. Preliminary studies were performed for the purpose of identifying the appropriate method of parching, sample preparation was done by removal of bitterness and accordingly percentage of processed quinoa was established through sensory evaluation.

Optimization
Parching of raw materials were tried to arrive at the desired processing method with optimum percentage yield as recommended by acceptability studies. All experimental samples were prepared using the method of (Amal *et al.* 2014) [2] with slight modification.

Different processing methods of parching were prepared by removal of bitter content of quinoa.

After primary processing (Over-night soaking and washing with tape water) for remove bitter content of quinoa seed, proper drying was done. After that the equilibrated grain were added in an iron frying pan with hot sand and parching temperature 160°C, 170°C, 180°C, 190°C for 15 sec, 20 sec, 25 sec and 30 second respectively maintained. When grain turned slight brown stopped the pan was removed from the flame. Only the most preferable of those processing methods was selected through sensory evaluation.

Physico-Chemical properties of raw materials and processed products were evaluated as given following methodology:

1000 seed weight

Neat, clean and sorted 1000 grains weight was measured by electronic balance and average weight was calculated.

Bulk density

The bulk density was calculated as weight of grain (g) divided by volume of grain (ml) and was expressed as g per ml which was reported by Vilche *et al.* 2003 [26].

Water absorption Capacity

Absorption capacity is expressed in grams of water absorbed per gram of sample. (Onwuka 2005) [19].

Expansion Volume

To determine swelling capacity by using the formula (Final volume – Initial volume) of known weight.

Colour measurement

Colour quality of the samples was estimated by using Hunter lab colorimeter (Colour Quest XE Hunter Lab, USA).

Proximate analysis

Moisture, protein, carbohydrate, fat, crude fiber, ash were measured according methods describing by AOAC 2000 [3].

Determination of minerals

Minerals content like calcium, magnesium, iron and zinc were determined by using titration and spectrophotometric method respectively.

Determination of *In vitro* Protein Digestibility and *In vitro* Starch Digestibility

IVPD and IVSD was determined by the method given by the Singh *et al*, 1982 [22].

Statistical Analysis

For comparison of nutrient content of raw and parched products of quinoa two way analysis of variance test was applied on the means of three replications for different combinations. The analysis of variance revealed at significance at $P< 0.05$ level. The standard error (SE) and critical difference (CD) at 5 percent level were mentioned where required.

Results and Discussion

On the basis of triplicate analysis, data is obtained and presented as result whish in line with various previous research and trails. Physical properties of raw grains and processed products of quinoa are presented in Table 1.

It was revealed that maximum (2.60 g) thousand seed weight was found in raw quinoa whereas significantly lower thousand seed weight found in parching. Mean 1000-seed weight of quinoa was found to be around 2.7 g as reported by Bhargava *et al.* 2006 [5], and a range of 1.5 g to 4.5 g has been observed among varieties (Wu *et al.* 2014) [27].

It was exhibited from table 1 that highest bulk density (0.68 g/ml) was observed in raw quinoa sample whereas parched quinoa bulk density observed as 0.32-0.45 g/ml in different samples.

Table 1: Physical Characteristics of raw and parched quinoa

Samples	Parching Temp. (°C)	Parching Time (s)	Bulk Density (g/ml)	Expansion Volume (ml)	Water Absorption Capacity (%)	Thousand Seed Weight (g)
Raw quinoa	-	-	0.68	-	147	2.60
Parched Quinoa	160	15	0.45	7.30	180	2.41
		20	0.43	7.31	185	2.40
		25	0.41	7.32	187	2.39
		30	0.40	7.35	188	2.39
	170	15	0.39	7.37	190	2.38
		20	0.39	7.39	190	2.38
		25	0.38	7.40	191	2.37
		30	0.37	7.42	192	2.36
	180	15	0.36	7.43	192	2.36
		20	0.36	7.45	193	2.35
		25	0.35	7.49	194	2.34
		30	0.34	7.50	194	2.34
	190	15	0.34	7.55	195	2.33
		20	0.33	7.60	195	2.32
		25	0.32	7.60	198	2.32
		30	0.32	7.65	201	2.31

Bulk density of raw quinoa 0.68 g/ml and the similar range (0.66 to 0.75 g/ml) in most varieties was observed by Wu *et al.* 2014 [27]. Similarly, a study conducted by Balasubramanian and Viswanathan (2010) [4] reported that, at higher moisture levels, bulk density will be higher.

Water absorption capacity of parched quinoa ranged from 180 to 201 which was in tune with the findings of Vidyavati (2001) [25] where in hydration capacity of raw samples ranged from 0.82 to 1.45. Water absorption capacity of the sample depends on the protein, starch and fiber with starch showing the superior contribution (Farooq and Boye, 2011) [9]. It was observed that expansion volume of all parched quinoa was ranged from 7.30 to 7.65 ml whereas lowest (7.30 ml) was observed in parched samples which were parched at 160°C temperature for 15 s time. Thermal expansion changes the space between particles of a substance, which changes the volume of the substance while negligibly changing its mass (the negligible amount comes from energy-mass equivalence), thus changing its density, which has an effect on any buoyant forces acting on it. It was revealed from the table 2 that L* value slightly increased on parching and the highest (80.01) found in parched samples which was parched at 190 °C for 30 s time whereas lowest (78.00) was observed in parched at 170 °C for 20 s time.

Table 2: Hunter colour analysis of parched quinoa

Samples	Parching Temp. (°C)	Parching Time (s)	L* (Lightness)	a* (Redness)	b* (Yellowness)
Raw	-	-	78.65	2.70	23.60
Parched Quinoa	160	15	78.80	2.30	20.59
		20	78.81	2.21	20.40
		25	78.79	2.27	20.55
		30	78.85	2.20	20.13
	170	15	78.84	2.23	20.51
		20	78.00	2.17	20.24
		25	78.87	2.21	20.47
		30	78.05	2.19	20.45
	180	15	78.89	2.26	20.45
		20	78.10	2.15	20.51
		25	78.03	2.17	20.40
		30	79.10	2.12	20.33
	190	15	79.17	2.10	20.31
		20	79.25	2.09	20.57
		25	79.60	2.05	20.45
		30	80.01	2.03	20.23
S.Em			0.183	0.135	0.109
CD@ 5%			0.638	0.497	0.371

The highest (2.70) a* value was reported in raw quinoa while lowest (2.03) found in parched samples which was parched at 190°C for 30 s time. In case of b* value, the maximum (23.60) value was observed in raw quinoa whereas minimum (20.13) value which was exhibited in parched at 160°C for 30 s time. Chrome or colour intensity decreased significantly due to coating and processing compared to raw material, while hue and total colour change showed major increase for quinoa grains processed by parching. These colour changes were attributed to per carp damage, irregular grain expansion during puffing and starch gelatinization. Temperatures above 76.7 °C and moisture below 16.9% w/w during puffing promote caramelization and Maillard reactions of reducing sugars and the degradation of quinoa pigments (Coutinho *et al.*, 2013) [8]. Parched quinoa contains 8.31 to 8.70 g/100g moisture content. Moisture content of cereals and millets ranges from 10 to 14 per cent. Similar trend was also observed in raw quinoa samples under study which ranged from 11.20 to 12.35 per cent. Results shows significantly decreasing trend with respect to increasing temperature and time. The reason may be in case of puffing due to heating at high temperature there may be loss of moisture content. Similar trend was reported in popped finger millet varieties by Sahoo (2003) [21].

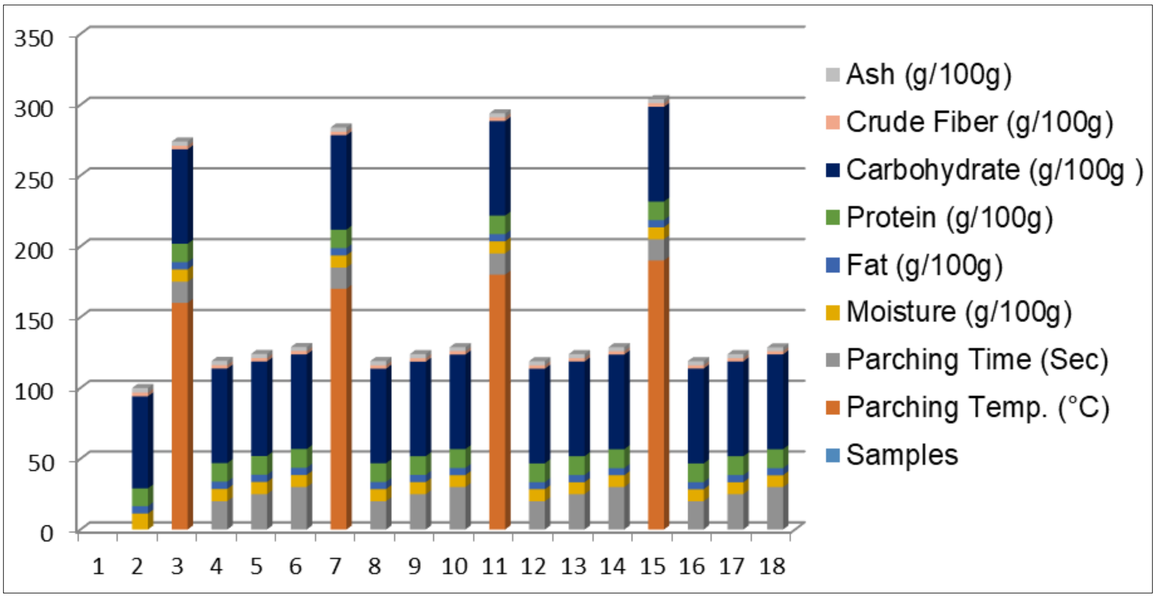

Fig 1: Proximate composition of parched quinoa

Protein content of raw quinoa was 12.61 g/100g which was on par with the results of the study conducted by Abugoch (2009) [1] in which the protein content of quinoa seeds contain 12-16% protein. Parched quinoa contains 13.02 to 13.35 g/100g protein that slightly more than raw quinoa. Since seed coat contains less protein than endosperm (Mac Masters *et al*., 1971) [13] and it was removed while parching, this might be the reason for increased protein content of parched grains.

In the present study the fat content of raw quinoa was 5.17 g/100g which falls within the range of fat content for various quinoa varieties reported by Miranda *et al*., 2013. Parched quinoa contained 5.05 to 5.15 g/100g fat. The significant decrease of fat on processing methods (*i.e*. Parching,) shown in findings. Carbohydrate content of raw quinoa seeds was observed as 65.11 g/100g, which is in accordance with the value reported by Marmouzi *et al*., 2015 [16]. However, the carbohydrate content of quinoa increased in parching and it ranged from 67.62 to 68.28 g/100g which may be due to the fact that puffed seeds were concentrated more with endosperm which contributes 94 per cent of starch to the kernel (Choudhury *et al.,* 2011) [6].

Raw quinoa seeds reported to have crude fiber content of 2.62 g/100g whereas parched quinoa samples contains 2.26 to 2.52 g/100g crude fiber. In this process, the seed coat gets removed to some extent, which could be the reason for lower fibre content in parched sample compared to that of raw samples. Similar trend was observed by Malleshi and Klopfenstein (1998) [14].

The raw quinoa contains ash content of 3.19 g/100g which is similar to the ash content reported by Miranda *et al*., 2012 in different varieties of *Chenopodium quinoa* seeds. However, the total ash content of the varieties decreased in parched quinoa contains as ranged from 1.98 to 2.93 g/100g. Similar findings were reported with regards to popped finger millet (Choudhury *et al*., 2011) [6].

The mineral content of quinoa seeds was observed as iron 5.77 mg/100g, Zinc 6.60 mg/100g, Calcium 85.30 mg/100g and Magnesium 182.40 mg/100g. The results represented in table 3 showed the parched samples of quinoa exhibited iron content from 3.67 to 4.66 mg/100g, Zinc between 4.70 to 5.20 mg/100g, Calcium from 46.70 to 65.32 mg/100g and magnesium from 166.10 to 171.38 mg/100g. The results shown in table 3 clearly indicates the mineral content of parched samples slightly decrease from raw quinoa.

Table 3: Mineral content of parched quinoa

Samples	Parching Temp. (°C)	Parching Time (s)	Iron (mg/100g)	Zinc (mg/100g)	Calcium (mg/100g)	Magnesium (mg/100g)
Raw			5.21	6.60	85.30	182.40
Parched Quinoa	160	15	4.66	5.20	65.32	171.38
		20	4.61	5.18	63.10	169.98
		25	4.58	5.12	61.56	169.85
		30	4.52	5.10	58.65	169.77
	170	15	4.57	5.15	60.24	170.69
		20	4.48	5.10	59.78	169.55
		25	4.45	4.97	55.37	169.37
		30	4.39	4.93	49.54	169.25
	180	15	4.50	5.09	56.34	169.92
		20	3.99	5.03	54.57	168.88
		25	3.95	4.85	53.97	168.59
		30	3.90	4.81	48.78	168.26
	190	15	4.46	5.02	51.35	169.03
		20	3.80	4.97	51.10	167.93
		25	3.73	4.73	50.36	167.05
		30	3.67	4.70	46.70	166.10
S.Em			0.067	0.005	0.041	0.011
CD@ 5%			0.198	0.014	0.124	0.031

Reduced level of mineral in parched samples could be due to greater concentration of minerals present in the germ and the bran layers than in endosperm (Mac Masters *et al.,* 1971) [13], which contribute to a greater extent towards the amount of total minerals content in whole seeds.

Table 4: *In vitro* protein digestibility (IVPD) and *In vitro* starch digestibility (IVSD) of parched quinoa

Samples	Parching Temp. (°C)	Parching Time (s)	IVPD (%)	IVSD (%)
Raw	-	-	75.35	67.75
Parched Quinoa	160	15	76.50	69.90
		20	76.80	71.32
		25	76.95	73.50
		30	77.13	74.13
	170	15	77.35	70.10
		20	77.40	72.05
		25	77.47	74.00
		30	77.51	74.60
	180	15	77.52	72.28
		20	76.53	73.02
		25	76.55	74.79
		30	76.57	75.63

	190	15	77.58	72.40
		20	77.60	73.83
		25	77.61	74.80
		30	77.63	75.70
S.Em			0.053	0.064
CD@ 5%			0.187	0.227

Raw quinoa seeds was exhibited to have 75.35% of IVPD and 67.75% of IVSD whereas parched quinoa samples reported between 76.50 to 77.63% of IVPD and 69.90 to 75.70% of IVSD. The results clearly showed significant increase of IVPD and IVSD as compared to raw quinoa on processing. This has been attributed to the release of starch granules from the protein matrix, making the starch content more susceptible to enzymatic digestion. An increase in digestibility after thermal treatments may be attributed to some factors like cell wall encapsulated starch, and physical disintegration of seeds as suggested by Tovar *et al*. 1991 [24].

The protein digestibility of quinoa increased significantly after parching. The increase in digestibility was recorded as 77.63% for parched quinoa. This might be due to the localized rupture of the cell wall which occurred in the expanded endosperm during popping (Hulse *et al*., 1980) [10].

4. Conclusion

In this study an attempt have been made to develop a quinoa based processed food with higher nutritive value. The results showed that acceptable processed products could be produced from quinoa by optimization of parching. Based on the optimization of processing methods, parched quinoa which was parched at 160°C for 30 s were found to be most acceptable products. The optimized quinoa showed good sensory acceptability revealing their potential for consumption by all type of population. Thus in the light of the scientific data it may be concluded that nutritional bioavailability and digestibility of quinoa could be improved by reducing its bitter content and in this regards the processing method contribute to enhancing utilization of quinoa based products. The addition of this product in the daily food can help to alleviate the deficit in protein and carbohydrate in the malnutrition of population.

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