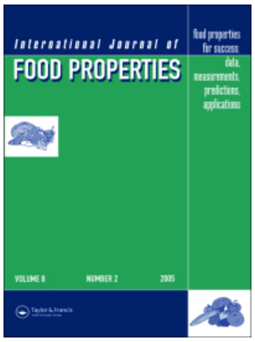

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Evaluation of starch digestibility of Andean crops oriented to healthy diet recommendation

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ABSTRACT

Starchy Andean crops are often underutilized by consumers, despite their nutritional properties. The starch digestibility of a food is an indicator of its nutritional quality, mainly to prevent cardiometabolic food-related diseases. Limited information on Andean crops' starch digestibility restricts nutritionists for designing adequate nutrition recommendations. This research evaluates the *in-vitro* starch digestibility of nine Andean crops flours and provides the knowledge, attitudes, and practices (KAP) survey about them among Ecuadorian nutritionists. The results were analyzed with a principal component analysis (PCA) using starch digestion characteristics (rapidly digested starch, RDS; slowly digested starch, SDS; resistant starch, RS; and estimated glycemic index, eGI). The findings showed that the studied crops could be divided into three groups: (1) *Puca shungo* potato with high RS, low RDS, SDS, and eGI. (2) *Melloco, zarandaja, firiguero*, and *centenario* with low RDS, SDS, eGI, and middle RS; (3) finally, *quinoa, amaranth, maca*, and *arracacha* with high RDS, SDS, low RS, and middle to high eGI. In addition, the KAP survey indicated that nutritionists lack knowledge about the starch digestibility of Andean crops, despite having positive attitudes toward recommending them. Our results would allow nutritionists to design healthy diet recommendations.

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Starch digestibility; Resistant starch; healthy diet recommendation; glycemic index; starch

Introduction

In Latin America, indigenous food systems are located in Andean regions with a high diversity of starchy crops, i.e., tubers, roots, beans, and cereals. Andean crops are underutilized cultivars that can contribute to the region's food security. The nutrient value of Andean crops has increased the attention of many researchers, especially for their protein value and their bioactive components. Little research has been done on Andean crops' starch digestibility, such as *quinoa*,[1,2] *amaranth*,[1,3] *arracacha*,[4,5] *maca*,[6] *melloco*,[7] *zarandaja*[8] and *firiguero*.[9] Other crops like *Puca Shungo* potatoehave not been explored yet.

The Andean region carries a double burden of malnutrition with a high prevalence of cardiometabolic diseases such as type 2 diabetics (T2D), obesity, and heart disease. These diseases are associated, among other causes, with high postprandial blood glucose levels linked to starchy food consumption.[10] The estimated glycemic index (eGI) indicates the postprandial glucose level produced by food consumption

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compared to a reference such as white bread. A low eGI (eGI<55) diet showed beneficial effects on preventing and treating cardiometabolic disease, cancer, and weight loss.[11] Indeed, Kaur *et al.* (2020)[12] demonstrated that lower eGI values showed a more suppressed postprandial glycemic response.

Different starch fractions have been classified according to their digestibility in the small intestine. Namely, rapidly digested starch (RDS), slowly digested starch (SDS), and resistant starch (RS).[13] SDS and RS are not fully digested in the small intestine; they pass to be fermented in the colon. Many reviews have shown the positive health benefits of the SDS and RS.[10,14,15] The metabolism of SDS in the small intestine results in a small peak of postprandial blood glucose, which is beneficial for hormonal and metabolic balance, with ultimate improvement in physical and mental performance, satiety control, and diabetes management.[16] On the other hand, RS goes to the large intestine, serving as a substrate for probiotic bacteria, resulting in a fermentation process associated with positive health outcomes.[14,15] RS has been associated with reducing the risk of colon cancer and contributing to appetite control.[17]

Despite the importance of starch digestibility on the nutritional characteristics of foods and the current health benefits of RS and SDS, their content is not presented in food composition tables (FCT). This lack of information limits nutritionists from designing adequate nutrition recommendations for starch consumption. In effect, nutritionists' knowledge, attitudes, and practices (KAP) regarding starch digestibility are essential for reducing malnutrition linked to cardiometabolic diseases. Nutritionists must be aware of local food starch digestibility to promote their consumption in response to food sovereignty. Consequently, this study determines the *in vitro* starch digestibility of flours from Andean grains, tubers, roots, and legumes as a helpful tool for nutritionists to make an appropriate healthy diet recommendation. Additionally, Ecuadorian nutritionists' current knowledge was evaluated through a KAP survey to suggest future nutritional educational strategies about the starch digestibility of Andean crops.

Materials and methods

Crops samples and flour preparation

Crop samples include Andean grains such as *amaranth* (*Amaranthus caudatus* var. INIAP-Alegría) and *quinoa* (*Chenopodium quinoa* var. INIAP Pata de venado); Andean tubers such as *maca* (*Lepidium meyenii), melloco* (*Ullucus tuberosus* var. Quillu) and native potato (Solanum andígena var. INIAP-*Puca Shungo*); one Andean root, which is *arracacha*, (*Arracacia xanthorrhiza* Bancroft); and Andean legumes, such as *zarandaja* (*Lablab purpureus* L. Sweet), *firiguero* (*Vigna unguiculata* L. beans), and bean (*Phaseolus vulgaris* L. var. INIAP-484 *Centenario*). *Arracacha* was acquired from Ambato's (Ecuador) local market. *Zarandaja* and *firiguero* were harvested at Loja's farms (southern Ecuador). The remaining samples were provided by the National Institute of Agricultural Research (INIAP) from Ecuador.

Arracacha and *puca shungo* (native potato) were peeled and sliced. Only *arracacha* was socked for 15 minutes in a 0.01% sodium metabisulfite solution. *Arracacha* and *puca shungo* were dried for 24 hours at 50°C. *Maca* and *melloco* were lyophilized (Labconco Lyph, FreeZone 4.5, Kansas, USA). *Quinoa, zarandaja, firiguero, centenario* and *amaranth* were harvested dry. All dry samples were milled and sieved in mesh No. 70 (212 μm). Raw flours were stored at room temperature [25 ± 2°C) for further analysis.

Starch hydrolysis

In vitro starch digestibility was analyzed following the Goñi *et al.* (1997) [18] method using a microplate reader at 510 nm [Biotek Instruments, Winooski, United States]. The RDS hydrolyzed at 20 min, and SDS hydrolyzed between 20 and 120 min, were measured according to Englyst *et al.*(1992).[19]

RS was quantified with Megazyme Kit Resistant Starch K-RSTAR (Megazyme International Ireland Limited, Wicklow, Ireland]. In brief, the sample (100 ± 5 mg) was incubated with pancreatic α-amylase (AM) and amyloglucosidase (AMG) at 30°C for 16 hours. The resulting solution was washed twice with ethanol and centrifuged at 2000 × g for 10 minutes at 4°C. The resistant starch (RS) was recovered in the pellet, and 2 M KOH was added and shaken in an ice bath. The solution was then neutralized with acetate buffer and hydrolyzed with AMG at 50°C for 30 min. Hydrolyzed D-glucose was measured with glucose oxidase/peroxidase reagent (GOPOD) at 510 nm in a Synergy TM HTX Multi-Mode Microplate Reader [BioTek Instruments Inc.).

The kinetics of the *in vitro* starch digestibility was calculated by applying a nonlinear model proposed by Goñi *et al.* (1997) [18]:

$$C = C\infty \left(1 \;-\; e{-}^{kt}\right) \tag{1}$$

where C is the percentage of hydrolyzed starch at time t, $C\infty$ is the equilibrium percentage of hydrolyzed starch, and k is the kinetic constant. Nonlinear regression analysis in Statgraphics Centurion XVI was used to calculate the model's parameters. The eGI was obtained by using the equation eGI = 8.198 + 0.862 HI. The hydrolysis index (HI) was calculated by dividing the area under the starch hydrolysis curve of each sample by the area of white bread.

Nutritionist online survey

A KAP survey related to starch digestibility of Andean crops was generated using Google forms; two websites were used to launch the survey: one on the highlands and one on the coastal region. Nutritionists' participation was voluntary and anonymous, responding to the written consent and the questionnaire in Spanish. Their nutritionist diploma was validated using the person's identity number and the national registry for higher education (SENESCYT) open website. Those who did not hold a nutritionist diploma were excluded from the study. Ethical approval of survey protocols was waived by the local Ethics Committee of Escuela Superior Politécnica del Litoral (ESPOL) and complied with the rules of the Declaration of Helsinki. Internal codes were used to keep anonymity.

A semi structured questionnaire was presented to evaluate KAP among Ecuadorian nutritionists. They were assessed for the eGI, RS, and SDS of Ecuador's most traditionally recommended crops, i.e., *quinoa, arracacha, maca, and melloco*. Their knowledge was measured in 4 items about IG and RS content in studied crops. Their attitude was evaluated in 5 items about the importance of including IG, RS, RDS, and SDS in the Ecuadorian FCT, and their practice was estimated in 1 item about recommending Andean crops.

Statistical analysis

Statgraphics Centurion 16 (Statistical Graphics Corporation, UK) was used to perform all statistical analyses. Shapiro–Wilk analysis was applied to verify if the samples were parametric. The Bonferroni test was used to compare medians of nonparametric data with 95% confidence ($P < .05$). The results are presented as the median [25% quartile (Q1), 75% quartile (Q3)] for nonparametric data. The correlation analysis among variables was performed using Pearson correlation coefficients (r); only coefficients greater than 0.67 were considered. Principal component analysis (PCA) and cluster analysis were carried out to identify samples with similar characteristics. All analyses were performed four times.

Results and discussion

Starch digestibility

Table 1 shows the *in vitro* starch digestion characteristics (TS, RDS, SDS, RS, eGI) of raw flours from Andean crops. *Quinoa* and *maca* present a very high RDS content (>35 g/100 g), whereas legumes (*firiguero, centenario and zarandaja*) and *puca shungo* show low RDS content (<10%). The SDS results revealed that the Andean studied crops could be divided into high SDS (>35 g/100 g) integrated by *quinoa, maca, amaranth*, and *arracacha*. Middle SDS content (9 g/100 g – 20 g/100 g) included *firiguero, centenario*, and *melloco*. Finally, low SDS content [<4 g/100 g) was established by *puca shungo* and *zarandaja*. On the other hand, according to the classification of Goñi *et al.* (1996),[20] the RS content in *maca, centeno, amaranth*, and *quinoa* is very low [<2.5 g/100 g]. Jimenez *et al*. (2017)[1] also reported low amounts of RS in raw *quinoa* flour, showing that quinoa can be considered a food with a negligent RS content. A very high RS content (>15 g/100 g] was observed in *puca shungo*, while *melloco, zarandaja*, and *firiguero* presented high RS content [between 5 and 15 g/100 g). Pacheco *et al.* (2019)[7]observed similar results in *melloco* RS content. *Arracacha* presented an intermediate RS content (2.5 to 5 mg/100 g]. The Pearson analysis exhibits a strong negative correlation (r = −0.77, P = .00) between SDS and RS. Accordingly, *quinoa, maca, amaranth*, and *arracacha* present the highest SDS content and the lowest RS content. In contrast, *puca shungo* exhibits the highest RS content and the lowest SDS.

Previous studies about the starch digestibility of Andean foods have been reported, and their main results are presented as supplementary information (see supplementary data). Solaesa *et al.* (2019)[2] presented higher RDS and RS content and lower SDS content than our findings in *quinoa*. The SDS content found in arracacha is similar to those presented in Pinzon *et al.* (2020) [5] but the RS and RDS contents differ. In these cases, their starch hydrolysis methodology differs from ours. Therefore, it is necessary to consider the influence of starch digestibility methodology on the reported results.

Additionally, it is essential to consider the effect of botanical variety and processing techniques on starch digestibility. Processes such as defatting significantly reduce the SDS content in *quinoa*.[2] The authors[2] attribute this result to removing the lipid barrier that allows access of the digestive enzyme into the starch granule. In addition, thermal processing, such as cooking and dehydration, affected the starch digestibility fractions differently according to the treatment and the type of food. Pacheco *et al.* (2019)[7] showed a significant RS reduction when *melloco* was cooked. Also, Du *et al.* (2014)[21] showed an increased RDS and a reduction in SDS and RS in cooking *pinto* beans. A different result was found by Naiker *et al.* (2020)[8], they evaluated the effect of soaking, steaming, and dehydration on the *in vitro* starch digestibility of Lablab purpureus bean flour. Their findings showed that soaking and steaming increase SDS but reduce RS; in contrast, soaking, steaming, and dehydration significantly improved RS and reduced RDS.[8] They attributed the RS increment to the dehydration of gelatinized

Table 1. In-vitro starch digestion characteristics and its kinetics parameters.

Source	RDS (g/100 g)	SDS (g/100 g)	RS (g/100 g)	C_∞ (g/100 g)	*K* (min^{-1})	eGI
Quinoa	38.40 (33.57; 43.31)^{c}	49.21 (43.23; 50.96)^{d}	0.37 (0.35; 0.44)^{a}	77.49 (77.48; 79.89)^{e}	0.026 (0.025; 0.028)^{abc}	91.15 (89.64; 91.31)^{d}
Amaranth	22.33 (21.64; 23.25)^{b}	35.30 (33.88; ^{36}.60)^{c}	0.77 (0.75;0.78)^{a}	59.97 (57.63; 64.55)^{d}	0.023 (0.022; 0.025)^{ab}	68.35 (67.04; 74.22)^{c}
Arracacha	25.92 (25.73; 28.50)^{b}	27.62 (26.79; 28.57)^{c}	2.94 (2.89; 3.00)^{a}	48.39 (48.11; 52.95)^{c}	0.037 (0.036; 0.038)^{bc}	62.91 (62.58; 68.21)^{c}
Melloco	8.35 (7.60; 11. 80)^{a}	9.05 (8.97; 9.29)^{ab}	9.29 (9.05; 9.33)^{b}	15.42 (14.61; 16.02)^{a}	0.032 (0.025; 0.038)^{bc}	24.83 (23.83; 25.72)^{ab}
Maca	40.76 (35.76; 44.36)^{c}	48.98 (44.07; 55.00)^{d}	1.90 (1.79; 1.95)^{a}	75.59 (75.13; 77.14)^{e}	0.041 (0.039; 0.042)^{c}	95.12 (94.99; 96.03)^{d}
Zarandaja	5.49 (5.29; 6.25)^{a}	6.89 (6.53; 7.51)^{a}	12.20 (12.16; 12.29)^{c}	9.24 (9.08; 10.19)^{a}	0.039 (0.037; 0.040)^{c}	18.72 (18.54; 19.81)^{a}
Firiguero (cowpea)	5.03 (4.28; 8.22)^{a}	9.33 (9.21; 9.68)^{ab}	6.25 (5.13. 7.37)^{b}	14.89 (14.66; 15.10)^{a}	0.014 (0.013; 0.016)^{a}	20.59 (19.98; 21.53)^{a}
Centenario	8.31 (8.21; 9.26)^{a}	15.46 (14.99; 15.58)^{b}	2.28 (2.06; 2.49)^{b}	25.48 (24.52; 28.25)^{b}	0.017 (0.016; 0.018)^{a}	31.81 (30.44; 33.94)^{b}
Puca Shungo	7.38 (7.20; 7.79)^{a}	3.66 (3.31; 4.13)^{a}	18.38 (17.33; 21.30)^{d}	8.99 (8.82; 10.03)^{a}	0.100 (0.092; 0.122)^{d}	19.55 (19.45; 20.79)^{a}

The results were no parametric data presented as median (Q1, Q3). Values followed by different letters within a row denote significant differences (P < 0.05). RDS: rapidly digesting starch, SDS: slowly digesting starch, RS: Resistant Starch, C_∞: equilibrium concentration of starch hydrolyzed after 180 min, k: kinetic constant, eGI: Estimated glycemic index. (n = 4).

starch, increasing retrograded amylose.[8] It is essential to consider the effect of processing on starch digestibility; the results presented in Table 1 are based on raw samples. The type and cooking preparation could increase the starch digestibility of our results. Lal *et al.* (2021)[22] mentioned that food (with high RS and low eGI) could be suitable for an obese and diabetic person when it is cooked with additional processing (retrogradation, fermentation, or parboiling) or food condiment. Overall, nutritionists must be aware of the crop species, variety, and the effect of processing on starch digestibility before making healthy diet recommendations.

The values eGI in Table 1 show that *quinoa* and *maca* have the highest eGI (eGI>70), followed by *amaranth* and *arracacha*, with a moderated eGI (55 < eGI < 70). These results imply that these crops should not be recommended for patients with cardiometabolic diseases. However, these findings need to be interpreted with caution because eGI only reflects the ability of food to increase blood glucose levels without considering the available carbohydrates in the food.[23] The glycemic load [GL) considers these aspects and should be more appropriate to be used when recommending foods for glucose control. According toLal *et al.* (2021)[22], long-term consumption of a carbohydrate-rich diet with high GL and high eGI, linked to a sedentary lifestyle and fat-rich diet, increases the risk of cardiovascular disease, type II diabetes, and colon cancer. Nevertheless, there are many contradictory studies about the association between eGI, GL, and available carbohydrates with cardiometabolic diseases. Indeed, Vega-Lopez *et al.* (2018)[24] suggested that type 2 diabetes risk seems to have a stronger association with GL than with GI. Additionally, according to these researchers, dietary fiber and total carbohydrate intake could contribute to the observed differences. Recently, Zhang *et al.* (2022)[23] presented dietary recommendations for different populations considering the GL of whole grains and dietary fiber content. They recommended *quinoa* to elderly, fitness, obese and constipated people, even though it has a high eGI.

The kinetic parameters ($C\infty$ and k] of the *in vitro* starch digestibility obtained for 9 Andean crops are presented in Table 1. $C\infty$ represents the reaction endpoint of starch hydrolysis, and k represents the enzymatic hydrolysis rate. High k values indicate a faster digestion rate.[25] *Quinoa* presented the highest equilibrium percentage of starch hydrolysis ($C\infty$), followed by *maca, amaranth*, and *arracacha*. *Puca shungo* shows the lowest $C\infty$ but the highest k value. The Pearson analysis showed a strong positive correlation between $C\infty$ and eGI (r = 0.99, P = .00). Consequently, *puca shungo*, which has a rapid digestion rate (high k value), presented the lowest $C\infty$ and eGI. Additionally, this potato variety presents the highest RS content. Indeed, a strong negative correlation between $C\infty$ and RS (r = −0.81, P = .00) and eGI and RS (r = −0.78, P = .00) was observed, confirming previous studies.[22,26] This result shows that the amorphous zone of the potato starch granule is rapidly hydrolyzed until the enzyme meets the semicrystalline zone formed mainly by RS. On the other hand, *quinoa* and *maca* show high $C\infty$ and eGI values, but *maca* presented higher RS and k values than *quinoa*, whereas there is no statistical difference in RS among them, showing that *maca* has a higher digestive rate that could explain the highest eGI value. Also, this result indicates that *quinoa*, with high eGI (GI>70), has a low rate of starch hydrolysis, so it is important to consider the time it is digested in the body. All the legumes presented low k and $C\infty$ values. In general, starch legume contents are digested less than those from the studied roots, grains, and some tubers.

It is important to consider that many intrinsic and extrinsic factors influence starch digestibility. Previous studies indicated that starch digestibility depends on the botanical source, variety, and food processing techniques.[27–29] Moreover, the structural difference of the starch influences its digestibility.[10,27] According to the diffraction pattern in X-ray analysis, the type of starch structure differs among cereals, tubers, and legumes; they present different rate of starch digestibility.[29] In addition, the starch structure changes by processing, also affecting the starch digestibility. For instance, the starch gelatinization increases its digestibility and reduces RS because of the transition from crystalline to the amorphous state, making it more susceptible to enzyme hydrolysis.[28] On the other hand, a cooling process reduces the starch digestibility and increases the RS formation because of the increment of starch crystallinity by retrogradation.[28] In the current study, the crop flours were

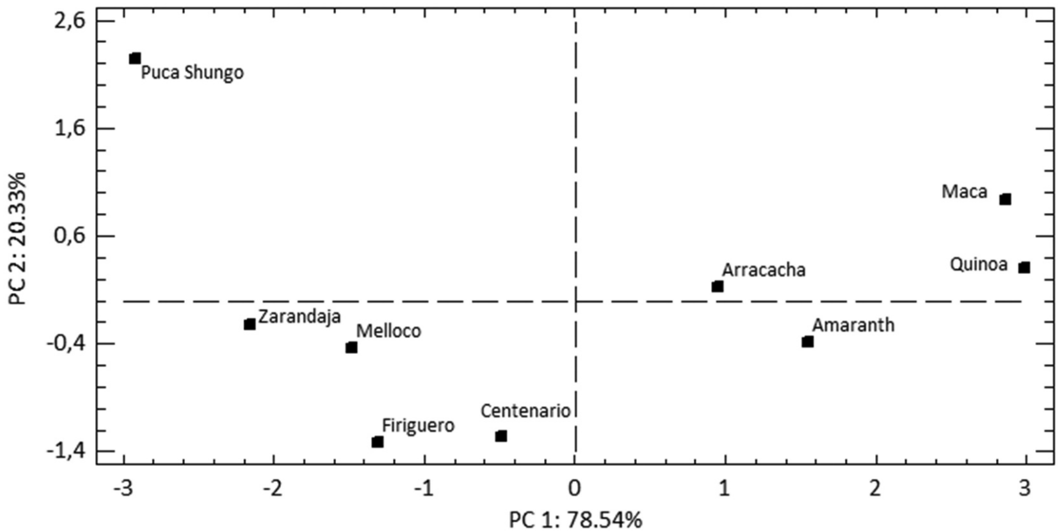

Figure 1. Principal components analysis score plots.

prepared in distinct ways, which could have affected the starch structure differently among samples. Therefore, starch's structural changes are fundamental for dietary strategies, particularly for preventive or therapeutic nutrition recommendations.

A principal component analysis (PCA) and a cluster analysis were performed to confirm our findings. The cluster analysis merged crops into three main groups. (1) *Quinoa, amaranth, maca*, and *arracacha*, (2) *melloco, zarandaja, firiguero*, and *centenario*, (3) the *puca shungo*. The PCA was analyzed using the *in vitro* starch digestion characteristics (RDS, SDS, RS, eGI) and its kinetics parameters ($C\infty$ and k). PC-1 (78.54%) and PC-2 (20.33%) explained 98.87% of the total variation in these parameters. The representation of the scores plot (Figure 1) confirms cluster analysis that the studied Andeans crops can be divided into three groups. The first group was segregated along PC1, grouping two grains (*quinoa* and *amaranth*), one tuber (*maca*), and one root (*arracacha*). This group can be distinguished with high starch digestibility, high SDS content, and low RS content. The second group comprises three legumes (*firiguero, centenario, zarandaja*) and one tuber (*melloco*) that appears in the oppositive corner of PC1 and PC2. It can be characterized by low RS and SDS content and low starch digestibility. *Puca shungo* forms the last group with a high RS content and low digestibility. These results show that legumes have less digestibility than cereals. Regarding the tubers, they were categorized into three different groups. As a previous study,[7] *melloco* presented low digestibility and low RS and SDS content. This tuber could be recommended as a source of energy and a healthy carbohydrate source. *Arracacha* presented high digestibility, making this root recommended for patients who have had episodes of diarrhea or postoperative periods.

Nutritionist online survey

A KAP survey was carried out to evaluate the Ecuadorian nutritionists' current knowledge about Andean crop starch digestibility and the importance of including eGI, RS, SDS, RDS in the Ecuadorian FCT. Table 2 shows the KAP of 62 Ecuadorian nutritionists who responded to the survey. Knowledge about the eGI value in Andean crops showed that less than 32% of the nutritionists answered correctly to the eGI of *quinoa, arracacha, maca*, and *melloco*. Less than 20% of nutritionists answer correctly about eGI of *maca* and *melloco*. The Ecuadorian nutritionists' knowledge of RS content in *quinoa* y *maca* was 25%.

Table 2. KAP survey to Ecuadorian nutritionist.

Correct knowledge about IG and RS content on Andean crops (n = 62)		
Knowledge about IG value in Andean crops	Quinoa (eGI>70)	24.19%
	Arracacha (eGI>70)	32.26%
	Maca (eGI>70)	14.52%
	Melloco (eGI<35)	17.74%
Knowledge about RS value in Andean crops	Quinoa (RS< 1 g/100 g)	24.19%
	Maca (RS< 1 g/100 g)	24.19%
Knowledge about the effect of processing in IG in Andean crops	Raw quinoa flour (eGI>70)	27.42%
	Quinoa bread (eGI>90)	17.74%
Knowledge about the effect of processing in RS in Andean crops	Raw quinoa flour (0.4 < RS< 0.6 g/100 g)	30.65%
	Cooked quinoa (RS<0.4 g/100 g)	25.81%
Attitude about starch digestibility fractions and Andean crops (n = 62)		
Attitude toward including eGI value on the nutritional composition table	Positive	62.90%
	Negative	27.42%
	Indifference	9.68%
Attitude toward including RS content on the nutritional composition table	Positive	45.16%
	Negative	45.16%
	Indifference	9.68%
Attitude toward including RDS content on the nutritional composition table	Positive	53.23%
	Negative	32.25%
	Indifference	14.52%
Attitude toward including SDS content on the nutritional composition table	Positive	64.52%
	Negative	20.96%
	Indifference	14.52%
Attitude to recommend Ecuadorian foods in nutritional health recommendation	Very important	77.42%
	Important	11.29%
	Indifference	11.29%
Practice about the nutritionist's confidence on their recommendation about low glycemic index foods		
Confidence about recommend Ecuadorian foods with low eGI without a food composition table	Confidence	19.36%
	Limited confidence	24.19%
	No confidence	8.06%
	Not answer	48.39%

Additionally, the survey shows that the knowledge about the effect of processing on eGI and RS in *quinoa* is low [less than 30% of nutritionists responded correctly). The survey reveals nutritionists' lack of knowledge about starch digestibility and fractions. This lack of knowledge could produce that the nutritionists make a wrong nutritional recommendation to cardiometabolic disease patients. Also, it causes less popular crops such as *puca shungo, centenario, firiguero*, and *zarandaja* to be absent in nutritional recommendations as nutraceutical foods for glucose management and appetite control. Recently, Delgado *et al.* (2021)[30] pointed out that the degree of processing and food matrix must be considered with food composition databases (FCD) for nutritionally balanced diets. As mentioned above, nutritionists should be aware of the food matrix botanical, structural, and processing characteristics to design healthy diet recommendations related to starch consumption.

Previous studies have evidenced the value of food composition databases and the need to update FCT in developing countries.[30,31] Table 2 shows the attitude of the Ecuadorian nutritionists about the importance of starch digestibility and fractions in the Ecuadorian FCT. More than 50% of the nutritionists showed a positive attitude toward including eGI, RDS, and SDS in the Ecuadorian FCT, whereas 45% of the nutritionists expressed a positive attitude toward RS. Recently, Delgado *et al.* (2021)[30] emphasized that the GI and RS should be included in FCD. In fact, only 19% of the nutritionists were confident in recommending low eGI foods without using a FCT, and 24% had limited confidence. In addition, 88.71% of the nutritionists indicated that it was "important" and "very important" to include Ecuadorian foods in nutritional health recommendations. These results show the importance of determining the starch digestibility of regional crops and publishing information using channels (FCT or FCD) accessible to nutritionists.

As a result, this survey reveals that a strategy for nutritionists' healthy diet recommendations could include starch digestibility and fractions in the Ecuadorian FCT. The results obtained in this research (Table 1) and the complementary table could be helpful for nutritionists in recommending *quinoa, amaranth, arracacha, melloco, maca, puca shungo, zarandaja, centenario*, and *firiguero* in Ecuadorian diets. Also, the survey shows the importance of updating concepts about RS and SDS content in Andean crops and the effect of processing on starch digestibility.

Conclusion

This research indicates that the starch nutritional characteristics of the studied Andean Crops differ among crops. The *in vitro* starch digestibility analysis of the studied Andean crops provides a tool for nutritionists to recommend a healthy diet. Professionals must be aware of the food processing effect on starch digestibility contained in these foods. The nutritional survey revealed a lack of knowledge from Ecuadorian nutritionists about starch digestibility. The scientific information must be visible to the nutritionist in the FCT to translate it to the consumers into familiar settings. Further research on the starch digestibility of traditional Ecuadorian food menus, including Andean crops, will be a direct tool for consumers to understand the eGI.

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Disclosure statement

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Ethics declaration

Ethical approval was waived by the local Ethics Committee of Escuela Superior Politécnica del Litoral (ESPOL) (IRB 2020 ESPOL-DEC-INV-OFC-0799-202) and complied with the rules of the Declaration of Helsinki.

Informed consent statement

Participants reacted positively to informed consent before responding to the online survey.

Data availability statement

The datasets generated during the current study are available from the corresponding author on reasonable request. https://espolec-my.sharepoint.com/:f:/g/personal/fcornejo_espol_edu_ec/Eil64gnXNFhKryGQAWtfjloBpwiiSA373BsaaKRT9ylAbg.

Author contributions

Conceptualization, formal analysis, methodology, and writing - original draft were performed by Cornejo F and Peñafiel D: all authors contributed to writing - review and editing, resources and funding acquisition commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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