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Rosa Huaraca Aparco
José María Arguedas National University. Professional School of Agroindustrial Engineering, Andahuaylas, Apurímac. Peru

Maria Del Carmen Delgado Laime
José María Arguedas National University, Professional School of Agroindustrial Engineering, Andahuaylas, Apurímac, Peru

Fredy Taípe Pardo
José María Arguedas National University, Professional School of Agroindustrial Engineering, Andahuaylas, Apurímac, Peru

Fidelia Tapia Tadeo
José María Arguedas National University, Professional School of Agroindustrial Engineering, Andahuaylas, Apurímac, Peru

Juan Alarcon Camacho
José María Arguedas National University, Professional School of Agroindustrial Engineering, Andahuaylas, Apurímac, Peru

Nolasco Carbaja Guido
José María Arguedas National University, Professional School of Agroindustrial Engineering, Andahuaylas, Apurímac, Peru

Corresponding Author:
Rosa Huaraca Aparco
José María Arguedas National University, Professional School of Agroindustrial Engineering, Andahuaylas, Apurímac, Peru

Phase transition characterization in sprouted quinoa flour (*Chenopodium quinoa* Willd.) variety Pasankalla

Rosa Huaraca Aparco, Maria Del Carmen Delgado Laime, Fredy Taípe Pardo, Fidelia Tapia Tadeo, Juan Alarcon Camacho and Nolasco Carbaja Guido

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Abstract
The thermal characteristics of phase transition in the field of food have significantly influenced consequently have attracted interest in his studies in different types of food products. Quinoa presents important nutritional sources, which facilitate its preparation of different processed foods. The objective of the research was to characterize the phase transition of germinated quinoa flour variety pasankalla. The analysis was performed using the differential scanning calorimetry (DSC) and thermogravimetric (TGA) technique. The results show that quinoa presents a thermal transition and enthalpy of high gelatinization, just as thermal modifications due to the effect of heat and humidity change the physicochemical properties of its starches.

Keywords: Quinoa, calorimetry, thermal transition

Introduction
Quinoa (*Chenopodium quinoa* Willd.), is a grain consumed due to its protein-rich content and the diversity of essential amino acids [1, 2]. The dietary fraction of fibers varies from 12 to 14% in quinoa varieties. In addition, these crops have significant amounts of vitamins, minerals, and antioxidant compounds [3-5]
Germination is a biological process that can be easily and cheaply applied to obtain new biotechnologically processed food products. The consumption of sprouted products is increasing because numerous studies have documented their advantages and health benefits [6, 7]. During the germination process hydrolytic enzymes are activated and they are also the most novel synthesized enzymes that, together with the reserve substances in the seed, are mobilized to be used in the initial growth of the seedling [8]. This process causes changes in the content and composition of proteins, carbohydrates and lipids. Proteins are hydrolyzed and consequently their digestibility so quinoa represents an interest in research especially in its flours, however, its thermal properties in terms of calorific values still require a thermal characterization.
Knowledge of thermal properties has been found to be essential for designing parameter processing to preserve the desired product quality. Thermal analysis can provide useful information related to feed quality and stability at storage temperatures, shelf life, changes that occur during post-processing at elevated temperatures, etc. [9]
The study of phase transitions has a great impact on the field of food industry, pharmaceutical industry and polymers. In food products, thermogravimeter analyses are a useful indicator for understanding the mechanism of food processing and for predicting the life of food products during storage [10]
Phase transition characterization by thermal analysis Scanning Difference Calorimetry (DSC) provides qualitative and quantitative information on the thermal properties of solid materials, such as melting and degradation temperatures, glass transition temperature, fusion and crystallization enthalpiy, specific and latent heats, polymorphism and purity of materials [11].

Thermogravimetry is primarily used to determine mass loss when a sample is heated, cooled, or maintained at a constant temperature in a controlled atmosphere. Its application is dedicated to the analysis of products, in the quantification of volatiles, degradation of matter, combustion reactions and residual matter. Analysis (TGA) is a useful and widely used tool for characterizing thermal decomposition (amount and rate of mass loss), thermal stability, and behavior of polymeric materials over time. Thermogram is the name given to the curve obtained after performing a thermal analysis. Usually, temperature or time is plotted on the x-axis, while the acquired signal is plotted on the y-axis. With simultaneous TGA-DSC, it is possible to differentiate fusion from degradation when these events occur over a narrow range of temperatures (e.g., in sugar-rich systems); melting and degradation temperatures are largely affected by the amount of water adsorbed.

Methods and Materials Sample

The research in the variety of quinoa Pasankalla, the samples were certified by the cooperative Machupicchu of the province of Andahuaylas Apurimac Region-Peru

Germination of grains

The washed grains without saponin were soaked in water (1: 5) for 6 h at room temperature. Water was drained and wet grains were spread in a thin layer in plastic trays covered with paper filters and incubated under controlled conditions: 22-24 °C and 80-90% relative humidity in darkness, with a time of 48 h where the sprouts reached the same radical length (1 to 1.5 cm). Germination capacity was determined according to Hager *et al*. (2014), counting germinated grains and expressing it as a percentage of the total number of grains. The sprouted grains were dried in a forced circulation furnace at 50 °C to constant weight. The dried grains were ground in a centrifugal mill (CHINCAN model FW 100, China) in polyethylene bags and stored at room temperature.

Phase transition characterization Differential Scanning Calorimetry (DSC).

To determine the gelatinization temperature (Tp) and gelatinization enthalpiy (ΔH) was carried out by a differential scanning calorimetry medium (TA Instruments DSC-2500), previously calibrated with indium of 99.99% purity. The samples were analyzed in airtight aluminum capsules and the measurement was made by comparing with the heat flow of a similar, empty capsule. The mass of the sample was 10.0±0.1mg, of which 80% corresponds to water and the remaining 20% corresponds to flour. After sealing the capsule the sample was left to stand for 30 minutes to homogenize the mixture. The heating was carried out at a heating rate of 5 °C/min, from room temperature to 120 °C, in a nitrogen atmosphere [3]. Thermogravimetric Analysis (TGA).

Thermogravimetry analyses were performed to determine the thermal stability of the flours. Analyses were performed taking into account standard measurement procedures TGA ASTM E1131-03 [11]. A TGA Q500 equipment from TA Instruments was used, previously calibrated with high purity nickel. The mass of the sample was 10.0±0.1mg, and they were analyzed in platinum cymbals for TGA. The heating was carried out in a controlled manner from 25◦C to 600◦C at a constant rate of 10◦C/min, in a nitrogen atmosphere. The percentage of moisture (Hm), percentage of carbohydrates (Stage 1 and Stage 2) and final amount of residues (Rs) were developed for each sample.

Results

Differential scanning calorimetry

Figure 1 shows the DSC thermogram of quinoa flour. Where the gelatinization thermal transition can be observed as an endothermic peak in the heat flow curve. The process begins at an initial temperature T0 = 165.80 ºC, the peak temperature (Tp) is the temperature where the highest values of heat absorption are recorded (12), which occurs at a temperature of ºC. The results also show that the transition occurs in a temperature range (ΔT=Tf- T0) of 10.49 ºC. The enthalpy, calculated with the area with the area under the peak curve represents the energy needed to carry out the gelatinization process is 175.95 J / g. The values obtained for the standard deviation of the gelatinization parameters indicate that the Tp for germinated quinoa flour assumes an average value of 112.48 ± 0.234 ºC and ΔT takes an average value of 11.16 ± 0.652.

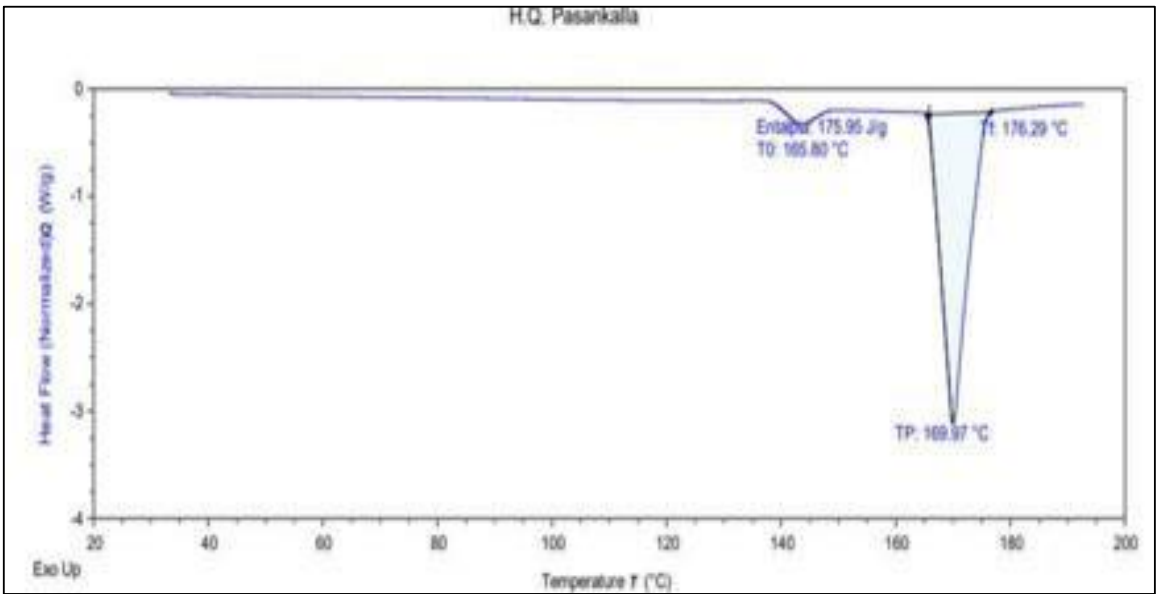

Fig 1: Thermogram of germinated quinoa flour variety Pasankalla

Thermogravimetric analysis

Figure 2 has been divided into three regions, related to the pronounced mass losses in the graphs for each sample; zone 1 corresponds to the loss of mass due to the moisture present in the sample where the amount of water available was 9.37% for the quinoa variety H.Q. Pasankalla; this decrease occurs between 100 and 200 ºC. The representative mass weight loss occurs in zone 2 in a temperature range between 200 ºC and 400 ºC, at this point carbohydrates, low molecular weight peptides and the total amount of starch present in the sample are broken down since it is weight loss is in the temperature range where starch degradation occurs. TGA thermogram in terms of the percentage of weight loss.

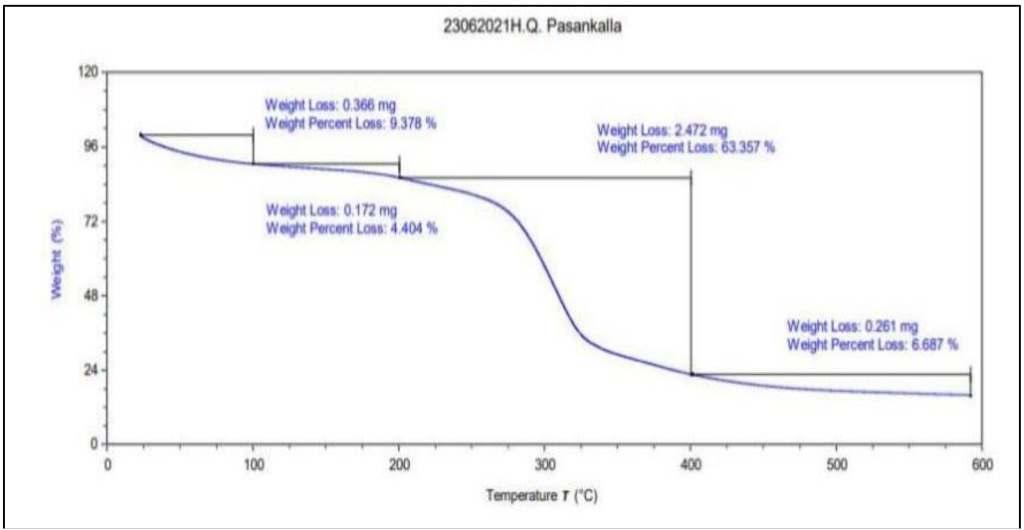

Fig 2: TGA thermogram of sprouted quinoa flour Variety Pasankalla

Conclusions

The phase transition characterization of germinated quinoa flour variety Pasankalla, presented attractive thermal transitions, facilitating the reduction of energy costs in different food processes. Sprouted quinoa flours can be interesting in studies for baking production and extruded products.

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