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Comparison between boiling and vacuum cooking (*sous-vide*) in the bioaccessibility of minerals in bovine liver samples

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A R T I C L E I N F O

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A B S T R A C T

Only some of ingested nutrients are available for absorption by the organism. The foods generally are submitted to some heat processing that may interfere in the bioaccessibility of nutrients. There are no studies of the influence of cooking under vacuum (*sous vide*) on the bioaccessibility of minerals. This study evaluated the *in vitro* bioaccessibility of Ca, Cu, Fe, K, Mg and Zn in bovine liver samples after traditional cooking in water and using the *sous vide* procedure. All heat treatments of bovine liver promoted the increase of the bioaccessibility of Ca, Cu, Fe, K and Mg, except for Zn when the effect was the opposite. The *sous vide* method provided higher bioaccessibility of these minerals than cooking in boiling water, except for K when both methods presented equivalent values. Samples of raw liver and liver cooked using *sous vide* method presented the following percentage of bioaccessible fraction, respectively: 39.7% and 95.8% (Ca), 8.78% and 26.9% (Cu), 8.80% and 39.5% (Fe), 30.2% and 42.6% (K), 26.4% and 43.9% (Mg), 24.8% and 36.3% (Zn). Thus, under the aspect of improvement availability of studied minerals by organism, the sous-vide technique was the most suitable to cook bovine liver.

1. Introduction

In general, the absorption of nutrients from food does not occur completely, only a part of the nutrients is available for this purpose. The bioaccessibility of nutrients can be defined by the fraction of them that is released from its matrix in the gastrointestinal tract and thus becomes available for intestinal absorption. The study of bioaccessibility of nutrients is conducted by *in vitro* methodologies, and is an indicator of the availability of the use of these substances by the body (Fernández-García, Carvajal-Lérida, & Pérez-Gálvez, 2009).

Many factors can affect the availability of nutrients from a foodstuff, such as the chemical form in which the nutrient reaches the intestine surface; its degree of solubilization; the possibility of ionization of soluble compounds; the presence of other substances that are ingested concomitantly and can compete with or stimulate the process of intestinal absorption of the nutrient (Huang et al., 2007).

Cooking food is an important procedure to improve characteristics like texture, softness and taste; however, this process can change the chemical form of the nutrients and, therefore, the availability of nutrients to be absorbed by the human body. During thermal processing, the application of heat hastens protein degradation, loss of weight and water that alter the physicochemical and nutritional qualities of the food (Domingo, 2011).

Food can be submitted to several methods of cooking like grilling, steaming, boiling in water, cooking under microwave radiation, *sous vide* cooking, *etc.* Each type of thermal process has different cooking conditions like time, temperature and medium of cooking; therefore the cooking techniques can have an influence on the nutrients bioaccessibility of the food in different ways. For example, the presence of oxygen and the temperature of approximately 100 °C characterize the traditional cooking technique of boiling the food in water; while a lower temperature, about 60 °C, for longer period of time (2–48 h) and absence of oxygen distinguish the *sous vide* cooking. However, there is scarce information about the effects of heating treatments on bioaccessibility of nutrients as minerals. In a recent review, Cilla, Bosch, Barberá, & Alegría (2016), describe the effect of food processing on bioactivities of various compounds, including some minerals in several cereal, fruit and milk samples. The authors describe the decrease of bioaccessibility for the minerals studied when the samples are submitted to cooking processes. In this review, there were no meat samples mentioned.

The *sous vide* is a modern cooking process originated in France and

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differs from traditional cooking methods mainly due to two factors: the raw food is vacuum-sealed in heat-stable, food-grade plastic pouches (*i.e.* in an anaerobic environment and without contact of the food with the water cooking), and the food is cooked using precisely controlled heating. Vacuum-sealing allows heat to be efficiently transferred from the water (or steam) to the food; it inhibits oxidation of food constituents and prevents evaporative losses of volatiles substances and moisture during cooking (Baldwin, 2012). Despite the fact that the *sous vide* cooking technique seems to be interesting from the nutritional aspect, no research could be found in the literature that investigates the influence of its peculiar cooking conditions on the bioaccessibility of inorganic nutrients in food.

Macro and microminerals play diverse functions in human organism being involved with many enzymatic reactions, macronutrient synthesis and physiological processes. Some works shows the influence of heat treatments on bioaccessibility of minerals (Cu, Fe, Se and Zn) and toxic elements (As, Cd, Hg and Pb) but they are limited to more traditional cooking procedures, none evaluated the *sous vide* cooking (Afonso et al., 2015; Carvalho, 2016; He, Ke, & Wang, 2010; Hemalatha, Platel, & Srinivasan, 2007; Houlbrèque et al., 2011; Matos et al., 2015; Maulvault et al., 2011; Perello, Marti, Llobet, & Domingo, 2008; Wang, Duan, & Teng, 2014).

Meat, including offal meats such as liver, is an important source of minerals, especially iron, selenium and zinc, covering up to 50% of the Recommended Dietary Allowance (RDA) for these minerals (Pereira, Cardoso, & Vicente, 2013). It is important to consider the influence of cooking techniques on the bioaccessibility of nutrients considering that humans do not eat raw meat. Cooking of meat is essential to achieve a palatable and safe product (Domingo, 2011; Tornberg, 2005). Conformational changes and aggregations of meat proteins occur under heating. The meat proteins (sarcoplasmic, myofibrillar and connective) can present different behaviors depending on the cooking conditions.

It is known that by applying an elevated temperature to the meat, its proteins are denatured and the Maillard's reaction occurs, responsible for producing components that will not be absorbed and utilized by the human body (Sgarbieri, 1996). Since many minerals are associated with or compose proteins in meats, the bioaccessibility of minerals in this food likely change according to the kind of cooking technique used.

The main purpose of this work is to evaluate the effect of heating processes on the bioaccessibility of macro and micro minerals (Ca, Cu, Fe, K, Mg and Zn) in bovine liver samples. The novelty of this research is comparing a vacuum heating process (*sous vide*) with a traditional cooking method (cooking in water boiling). The bioaccessibility of minerals was studied by use of *in vitro* method and its quantification was performed by inductively coupled plasma optical emission spectrometry (ICP OES).

2. Materials and methods

2.1. Samples

A sample of approximately 1.0 kg of bovine liver was purchased in the local market in the city of Fortaleza, Ceará, Brazil. The raw liver was cleaned with the removal of the protective skin and cut into cubes of approximately 2.0 × 2.0 cm. The sample was homogenized manually and stored in a refrigerator at 10 °C until it was analyzed. No condiment was added to the sample.

2.2. Reagents and solutions

Solutions were prepared using ultrapure water (resistivity of 18.2 MΩ cm) obtained from the Milli-Q water purification system (Millipore, Bedford, MA, USA). All glassware was immersed in nitric acid 10% $v\ v^{-1}$ (Vetec, Rio de Janeiro, Brazil) for 24 h, after rinsing using ultrapure water.

All reagents used in the experiments were of analytical grade. In total decomposition of the samples were employed HNO_3 65% $w\ w^{-1}$ (Vetec, Rio de Janeiro, Brazil) and H_2O_2 30% $w\ w^{-1}$ (Vetec). The reference solutions were prepared after successive dilutions from 1000 $mg\ L^{-1}$ Ca, Cu, Fe, K, Mg and Zn stock solutions (Acros, Geel, Belgium).

The solution HCl 0.1 $mol\ L^{-1}$ used in the study of bioaccessibility was prepared by diluting HCl 37% $w\ w^{-1}$ (Vetec, Rio de Janeiro, Brazil) and standardized with NaOH (Vetec, Rio de Janeiro, Brazil) standard solution 0.5 $mol\ L^{-1}$.

Gastric solution used in simulating gastrointestinal digestion was prepared by dissolving 500 mg of pepsin (Sigma-Aldrich, St. Louis, Missouri, EUA) in 50 mL of 0.15 $mol\ L^{-1}$ NaCl solution. The intestinal solution was prepared by dissolving 1500 mg of pancreatin (Sigma-Aldrich, St. Louis, Missouri, EUA) and 75 mg bile salts (Sigma-Aldrich, St. Louis, Missouri, EUA) in 50 mL of ultrapure water.

Certified reference material of bovine muscle powder (beef) (National Institute of Standards & Technology, Reference Material – 8414 (NIST/RM – 8414)) was used to verify the accuracy of the analyses.

2.3. Instrumentation

A closed microwave oven system Multiwave (Anton Paar, Austria) equipped with a rotor with 6 quartz vials of 50 mL was used for total wet decomposition of samples.

In the thermal processing of the samples, a vacuum sealer (Polishop®) was used to seal the samples, under vacuum using a special plastic available for the sealer manufacturer and thermostatic bath Dubnop (MA-0.92, Marconi®) was used for the *sous vide* cooking. Cooking by boiling was performed on a conventional stove (Supreme, DAKO®) in a stainless steel pan with a 1.0 L capacity (Solar, Tramontina®).

The thermostatic bath Dubnop was also used for incubation of *in vitro* gastrointestinal digestion, and the decomposition of the bioaccessible fraction was performed in a Tecnal TE-007D digester heating block (Piracicaba, São Paulo, Brazil) equipped with 15 Teflon® tubes with lids.

Samples were dried in an oven (Micronal, Piracicaba, São Paulo, Brazil).

The determination of minerals was carried out using an Inductively Coupled Plasma Optical Emission Spectrometer (ICP OES) (PerkinElmer, USA), Optima 4300 Series Dual View. The ICP OES parameters used are described in Table 1.

Table 1
Instrumental parameters of ICP OES used in the quantification of minerals.

Operational parameters ICP OES	
Nebulization chamber	Double-pass
Nebulizer	Cross-flow
Alumina injector (mm I.D.)	2.4
Generator frequency (MHz)	40
Radio-frequency power (W)	1100
Argon plasma flow rate ($L\ min^{-1}$)	15
Nebulization argon flow rate ($L\ min^{-1}$)	0.8
Auxiliary argon flow rate ($L\ min^{-1}$)	0.5
Sample flow rate ($L\ min^{-1}$)	1.4
Analytical wavelength (nm)	
Ca[a]	317.933 (II)
Cu[b]	324.752 (I)
Fe[b]	259.939 (II)
K[a]	766.490 (I)
Mg[a]	285.213 (I)
Zn[b]	213.857 (I)

(I) Represents the atomic line and (II) the ionic line.
[a] Radial view measurement.
[b] Axial view measurement.