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Life-cycle assessment of fresh and frozen chestnut

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ABSTRACT

Life-cycle assessment (LCA) has been applied to calculate the environmental impacts of various nuts; however, no studies were found for chestnut. This article presents a LCA of fresh and frozen chestnut produced in Portugal, intended both for export and domestic consumption. A "cradle-to-plate" life-cycle model was implemented considering cultivation, two types of processing (fresh and frozen chestnut), domestic and international distribution, retail, home storage, and cooking. Different markets (consumer locations) and alternative transport modes were assessed. Variability in cultivation and two alternative household storage times for frozen chestnut (45 days or six months) were also analyzed. Cultivation contributed most to the life-cycle impacts of both fresh and frozen chestnut (from 34% to 98%), mainly due to diesel and fertilizer use. Frozen chestnut presented higher impacts than fresh due to higher energy requirements for frozen storage (factory, retail and household) and processing losses. Post-harvest stages, particularly home storage and cooking, contribute significantly to life-cycle impacts. Important differences between the locations of final consumption were found due to differences in the electricity mix of the various countries. Furthermore, increasing storage time in the home freezer from 45 days to six months can lead to considerably higher life-cycle impacts. The consumption of products out of season can present significantly higher impacts than fresh; however, chestnut (fresh or frozen) shipped by air showed higher impacts than off-season. To mitigate the environmental impacts of chestnut, it is important to improve fertilizer and fuel use, as well as to reduce energy use in storage and cooking.

1. Introduction

For thousands of years, chestnut has been providing important nutritional, cultural and economic resources to civilizations, namely in Europe (*Castanea sativa* Mill.), Asia (*Castanea mollissima* and *Castanea crenata*) and North America (*Castanea dentata*) (Hunt et al., 2012). Optimum growing conditions for the chestnut tree are located at altitudes higher than 500 m with low temperatures in winter, as can be found in northeast Portugal (Ribeiro et al., 2007). In 2013, Portugal was the third largest producer of chestnut in Europe (EU 28) and the seventh worldwide, with an annual production of 24.7 thousand tonnes, and an orchard area of 35 thousand hectares (FAO, 2015; INE, 2015). The north of the country stands out as the main production region (provinces of Trás-os-Montes, Minho and Beira Alta, representing 84% of production and 88% of the chestnut orchard area, INE, 2015). Most Portuguese chestnut production (about 77% in 2013) is exported (INE, 2015): frozen chestnut is mainly exported to France, Italy and Spain, whereas fresh chestnut mainly to Brazil and Europe (Matos, 2003). The remaining production is for domestic consumption.

To assess the environmental impacts of food, it is crucial to use a holistic approach, since food systems are complex and can involve burden shifting between the main phases: i) production, including cultivation, processing and packaging; ii) distribution, including transport, retail and storage; iii) consumption, including food preparation and storage at home; and finally iv) waste generation and management. The life-cycle assessment (LCA) methodology provides an integrated analysis of the environmental impacts of a product or service and has been applied to a wide range of agricultural products; however, to the authors' knowledge, there are no published articles on the LCA of chestnut. A literature review to LCA of nut orchards pointed out studies for almonds, walnuts, hazelnuts and pistachio (Kendall et al., 2015; Marvinney et al., 2014; Venkat, 2012; Nemecek et al., 2011). These studies focused on either a cradle-to-farm or cradle-to-factory gate perspective, but not addressing distribution, retailing and consumption. Beccaro et al. (2014) presented an ecological footprint analysis of chestnut cultivation in Italy focusing on the nursery production system.

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The aim of this article is to assess the environmental impacts of fresh and frozen chestnut produced in Portugal, intended both for export and domestic consumption. For this purpose, a life-cycle model was developed considering: chestnut cultivation; two types of processing (fresh and frozen chestnut) in an industrial plant; domestic and international distribution (addressing alternative means of transport and refrigeration requirements); retail, final storage, and cooking (boiling) of chestnut. Environmental impacts were assessed for five categories (ReCiPe method, Goedkoop et al., 2013) and the life-cycle non-renewable energy requirements of fresh and frozen chestnut were calculated via the CED method (cumulative energy demand, Frischknecht et al., 2007). This article builds upon our preliminary work presented in the MSc Thesis of Rosa (2014) and two short conference papers (Rosa et al., 2015a, b).

2. Life-cycle model and inventory

A life-cycle model for fresh and frozen chestnut was implemented for a functional unit of 1 kg of edible chestnut kernel (fresh and frozen) at consumer, including storage and preparation at household. The main stages included in the system boundaries are chestnut cultivation, processing, distribution, retailing and home consumption (Fig. 1). Cultivation data was collected for distinct producers (years 2010–2012), addressing material and energy inputs for field operations, harvest and transport. The fresh and frozen chestnut processing lines of an industrial plant in the north of Portugal were assessed: to produce 1 kg of edible fresh chestnut kernel, 1.68 kg of harvested chestnut were required, whereas to produce 1 kg of edible frozen chestnut kernel, 2 kg were needed. Domestic (Lisbon) and international distribution (France, Italy and Brazil) of both fresh and frozen chestnut were studied, addressing alternative means of transport (truck, ship, airplane) and refrigeration requirements. Transport to a regional distribution center (RDC) and to a supermarket was included, as well as the energy required for fresh and frozen storage. The household stage included consumer transport from the supermarket to the house, energy consumption with storage (for frozen chestnut, two alternative durations of storage in the home freezer were investigated, 45 days and six months) and cooking (boiling).

A life-cycle inventory was implemented for chestnut cultivation and processing in northern Portugal (Sections 2.1 and 2.2), for domestic distribution and export to the most common destinations of both fresh and frozen chestnut (Section 2.3), for retail (Section 2.4) and for chestnut preparation prior to consumption at household (Section 2.5).

2.1. Cultivation

Two chestnut producers from northern Portugal were analyzed (P1 and P2). The chestnut tree was in full production for both producers and none of them performed irrigation (it is not a common practice in Portugal). The main agricultural practices accounted for were soil management, fertilization, pruning, pesticide treatments and harvesting. The nursery stage was not considered as it was common for farmers to use small wild chestnut trees and graft them with the desired varieties (Costa et al., 2008). Unlike other cultures whose cycle completes in less than a year,

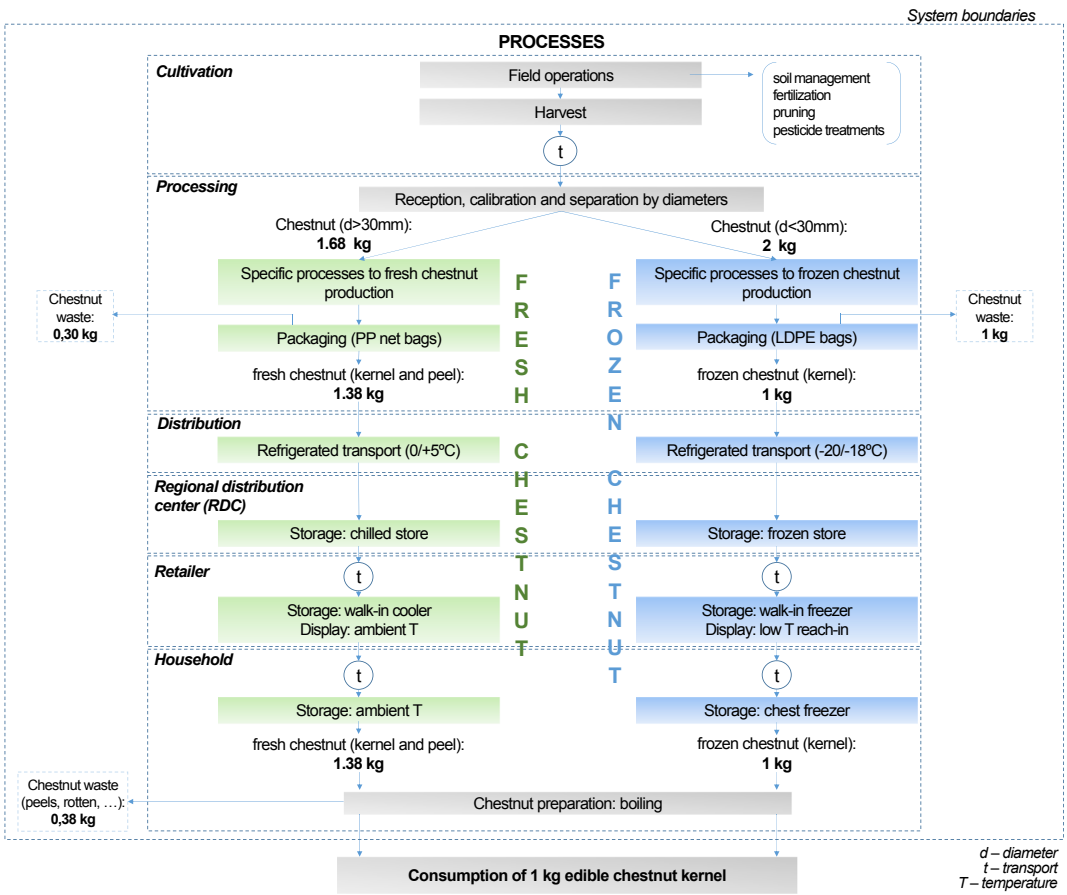

Fig. 1. Production chain of fresh and frozen chestnut (from cradle-to-plate).

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