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Fuel properties of avocado stone

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HIGHLIGHTS

- The consumption of avocado (*Persea americana* L.) has increased worldwide in recent years.
- The avocado stone was obtained from avocado industry.
- Till now avocado stone as a thermal energy source was not studied.
- The HHV obtained for avocado stone was 19.145 MJ/kg.
- The avocado stone added in biofuel technologies offers new perspectives for its valorisation.

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ABSTRACT

The consumption of avocado (*Persea americana* L.) has increased worldwide in recent years. Part of this food (skin and seed or stone) is lost during industrial processing. Avocado is the fourth largest selling tropical fruit in the world, with an estimated global production of 4,717,102 t in 2014 and an increase of 139% in the last 20 years. Residual biomass produced in the avocado sector results from the large amount of guacamole manufacturers that generate byproducts with potentially high energy content, suitable for thermal energy production. The main residue, avocado stone, could be an important biofuel, but its potential usefulness as biomass is unknown. Therefore, the main objective of this study is to describe avocado stone energetic properties and to evaluate these parameters before consumption. For this purpose, the parameters analysed in this wok were: Moisture (35.2%), HHV (19.145 MJ kg^{-1}), LHV (17.889 MJ kg^{-1}), elemental composition (e.g. 48.01% C, 5.755% H, 0.447% N), Ash content (2.86%), or oil content (1.715%). The results were compared to olive stone and almond shell, having intermediate values between both. Finally, a correlation between the ultimate analysis and higher heating values (HHV) of avocado stone has been evaluated, being the best correlation HHV = 0.4373 C − 1.6701 with a bias error of −0.94% which indicates that it can be successfully used as a faster tool to accurately estimate avocado stone HHV. As main conclusion, this work opens new perspectives for using of avocado stone as a fuel for domestic or industrial heating.

1. Introduction

The world population will probably exceed eleven billion by the end of the 21st century [1]. The proliferation of agricultural, industrial and domestic activities has increased the demand for energy remarkably, especially in emergent countries [2]. Fossil fuels such as petroleum, carbon and natural gas are the main sources of energy in the world (approximately 80% of total use). Although they are unacceptable in terms of long-term consequences, fossil fuels currently supply most of the world's energy needs. Thus, long-term action towards sustainable development and renewable energy resources appears to be the one of the most efficient and effective solutions. Among renewable energy sources, biomass is still one of the most studied, given that this type of resource exists worldwide and that useful biomass can be obtained from many types of agricultural waste and industry applications.

Biomass represents an abundant carbon-neutral renewable resource for the production of bioenergy and biomaterials, and its enhanced use would address several societal needs. The use of green energy sources, including biomass from forests and agricultural waste, has increased because of the need to reduce the environmental impact of traditional electricity and the generation

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of heat from fossil fuels, as well as the depletion of these resources and the increasing prices of fossil fuels [3,4]. It has been estimated that in developed countries, biomass provides 9–14% of the total energy supply. In developing countries, this contribution is higher: between one fifth and one third [5]. Thus, biomass is a considerable source of energy for many of these developing countries, and most of this energy is not commercialised [6].

One of the primary advantages of biomass is that it can be burnt directly in waste conversion plants to produce electricity without any type of chemical processing [7]. Biomass can also be burnt to produce heat in industrial plants and houses using boilers [8]. The main source of greenhouse gas emissions from a boiler is carbon dioxide (CO_2) produced from the combustion. Nevertheless, the use of plants for biofuel helps to maintain a constant level of carbon dioxide because plants fix CO_2 during growth. Thus, the thermal use of biomass is considered a solution to limit the greenhouse gas effect [5].

The development of a market for biomass has led to the current existence of a large variety of solid biofuels that can be used in heating systems in buildings and industries. Among them, pellets are produced industrially and are most frequently marketed for heating systems [9]. Additionally, woodchips are produced in the industries of first and second wood transformation and forest treatments (e.g., cutting, clearing, and wood energy production) [10]. With the increasing cost of wood biomass, other potentially less expensive biomass sources are being considered for combustion in small boilers, such as dried fruit shells [11,12], corn husks [13] or olive pits [14].

Currently, the primary biofuels used in small-scale combustion systems are derived from wood. The growing demand for these biofuels can lead to an unsustainable pressure on forests with negative consequences for the environment in general and, in the context of biodiversity, soil and water conservation [15]. To relieve some of this pressure while simultaneously increasing the availability of biomass for small-scale combustion systems and reducing CO_2 emissions, it is necessary to increase the use of alternative biofuels, as specified in the biomass classification promulgated by the European standard EN 14961-1. Furthermore, previous studies [11–13] have demonstrated that certain non-conventional raw materials have considerable potential for use in domestic pellet boilers as fuel.

Avocado is the fourth largest selling tropical fruit in the world. In 2014, production of 4,717,102 t was estimated, with an increase of 139% in the last 20 years (Fig. 1). Avocados are grown on all populated continents, especially North and Central America, with a global production percentage of 70.3%, followed by Africa with 15.2% and Asia with 10.9%. The top five producing countries are led by Mexico with 1,467,787 t, followed by the Dominican Republic with 387,546 t, Colombia with 303,340 t, Peru with 288,387 t and Indonesia with 276,311 t [16].

Avocados are often consumed fresh, but the processing industry for this product is increasing because of the increase in production and seasonality of the product. Products derived from avocados include drinks and ice cream, with guacamole being the most marketed product [17]. There are also examples of the production of avocado oil, which is of similar quality to olive oil [18]. Avocado processing generates large amount of waste, particularly the skin and seed or stone. The stone represents 15.0–16.0% of the fruit weight [19]. In Mexico, the leading producing country, 5% of fruit produced in 2008 was destined for processing (mostly for guacamole), producing 20,000 t of waste [20]. Some pharmacological properties are attributed to avocado stone because of the presence of fatty acids [21], polyphenols [22] and steroids [23]. The stone has been used since pre-Columbus times against diseases such as muscle pain, parasites and mycosis [24,25]. Although these subproducts may draw commercial interest in the cosmetic industry, they are discarded because they bring pollution issues in landfills [26] and to date have been valued for use as compost only [27].

The main objective of this study is to determine avocado seed properties and to evaluate energy parameters with the aim of describing the suitability of this biomass as a solid biofuel for domestic and industrial heating uses. For this purpose, mean values, normal distributions, intervals and deviations of these parameters have been obtained and studied to ensure repeatability and reproducibility of the quality parameter results. Finally, a model for estimating higher heating values (HHVs) of avocado stone has been determined and compared with other HHV predictions introduced by other researchers.

2. Materials and methods

2.1. Materials

A sampling plan was designed to collect avocado stone residues from different Andalusian guacamole industries: Avomix Factory,

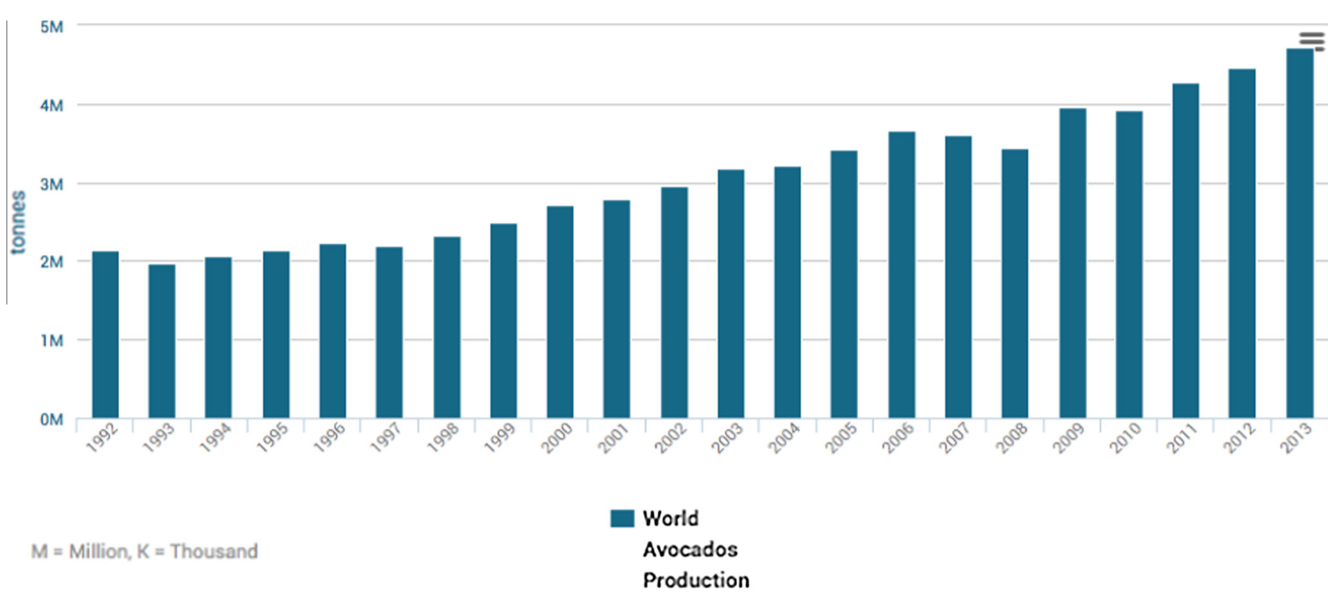

Fig. 1. Evolution of world avocado production over a 20-year period [25].