



A cura di

MARIA CLAUDIA LUCCHETTI, MARIA FRANCESCA RENZI

QUALITÀ, INNOVAZIONE
E SOSTENIBILITÀ NELLA
FILIERA AGRO-ALIMENTARE

Il contributo delle Scienze Merceologiche



Roma TrE-Press
2025





Dipartimento di Economia Aziendale



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Università degli Studi Roma Tre
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COLLANA DEL DIPARTIMENTO
DI ECONOMIA AZIENDALE

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Il contributo delle Scienze Merceologiche

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MARIA CLAUDIA LUCCHETTI, MARIA FRANCESCA RENZI



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Development of innovative supply chains for the valorization of Carob cultivation

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ABSTRACT

The carob tree is an arboreal species which represents a distinctive element of the Mediterranean ecosystems, often found as a spontaneous plant of the Mediterranean scrub, more easily diffused together with olive and citrus trees. As the carob survives in dry climates without additional irrigation, it can be considered an interesting crop for productive forestation, especially for areas characterized by higher water scarcity and specific soil constraints. The economic interest concerning carob cultivation has been underestimated for a long time. In fact, it has been considered for centuries as a low-cost and high-energy food mainly used for livestock feeding. This resulted in the gradual replacement of carob trees with more profitable value crops. Until the 60s the use of carobs was substantially linked to their pulp (on average about 90% of the total weight of the fruit) mainly used as animal feed, but, recently, the seed, useful for LBG (Locust Bean Gum) extraction, is increasing its commercial value. In this study the different varieties of carob were evaluated in order to identify the most suitable for the extraction of LBG, both in terms of yield and technological properties. The study is a preliminary step for the development and enhancement of an innovative agri-food supply chain which can realize high potential in terms of industrial use and added value, preserving and promoting the territory.

KEYWORDS: locust bean; crop alternative; agro-technological change; sustainable territorial regeneration; resilience.

1 Introduction

The carob tree is an arboreal evergreen dioecious tree characteristic of Mediterranean ecosystems, often present as a spontaneous plant, more

easily cultivated in association with olive or citrus trees. The official name of carob, *Ceratonia siliqua* L., derives from the Greek word “keras” and the Latin word “siliqua” that describes the hard texture of the pod (Gioxari et al., 2022). Its adaptation to the Mediterranean climate is essentially due to its physiological needs as it requires a mild climate and suffers from prolonged frosts (Tous et al., 2013).

Its origin as well as the original diffusion is uncertain since its cultivation goes back to the ancient times (the Bible also refers to the carob fruits with which the pigs were fed), but on the basis of the available knowledge, the carob is considered original and typical of the eastern Mediterranean area and seems to have been introduced into the countries of the western Mediterranean in Roman times, but it is believed that the varieties cultivated today derive from germplasm introduced during the Arab domination in the medieval era (Ramón-Laca & Mabblerly, 2004).

The carob pod is an edible bean, commonly known as locust bean, which comprises pulp (about 90%) and the seeds (about 10%) (Figure 1).

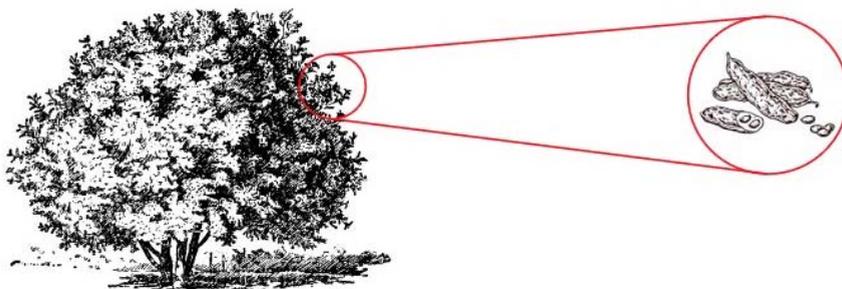


Figure 1 – Carob tree and pod

In terms of the use of carob fruits, it is possible to identify certain historical phases. The Middle Ages is definitely the time of maximum propagation of the harvest across the Mediterranean mainly used for food and feed purposes. The crop has spread to all the Mediterranean countries, especially Spain, Italy (Sicily) and the Greek Islands (MASAF, 2012).

Over time, the almost exclusive use of the products of this crop as animal feed, and its low economic value caused a drastic decrease in interest in the crop that remained limited to some marginal areas. The significant decrease in cultivation exposed carobs almost to the risk of extinction. As a result of the gradual abandonment of carob cultivation, the underused genetic resources of the species appeared to be at risk of erosion. More recently, instead, novel forms for the use of carob bean products, in the food,

feed and pharmaceuticals sectors, have been found. This may lead to market re-establishment with a re-evaluation of the species.

Carob based products in the marketplace are mainly represented by carob pulp, seeds and their derivatives. In the carob industry, after harvesting, the pods are crushed to separate seed and pulp that have different compositions and therefore different applications. The main products on the market are (Briamonte et al., 2007):

- pulp in the form of ground pulp, used in the animal feed industry;
- carob flour, a ground and powdered carob product, widely used in feeding stuffs, improving their palatability and giving them anti-diarrheal properties;
- carcao, a cocoa substitute, obtained from the processing of pods having the highest sugar content;
- seed flour, also known as Locust Bean Gum (LBG), produced by the processing of seeds, which contains thickening substances, precious for the many uses in the food industry;
- carob germ flour, obtained from seed processing and widely used in the feed industry, providing feed with a higher protein content, as well as a better level of palatability.

In addition to traditional feed uses, carob-based products have great potential, particularly in the agri-food and pharmaceutical sectors (Zhu et al., 2019).

2 Applications of carob pulp in the food and pharmaceutical industries

The primary carob products are carob flour, also called carob powder, and syrup, which are both obtained from the carob pulp.

Carob flour is important for a wide range of industrial processes of food products. It is produced by kibbling, roasting, and milling carob pods. Nowadays, carob powder has been incorporated as a healthy ingredient into many foods such as cereal based products, breakfast foods to improve the dough's rheological properties, gluten-free bread, dietary supplements, dairy drinks, biscuits, cakes and cookies. The high percentage of natural sugars (about 46%), which provides a healthier alternative to refined white sugar, makes it suitable especially for the confectionery industry. A particular flour, destined for human consumption, commercially called "carcao" is obtained by roasting locust beans under certain conditions. This process generates aromas very similar to cocoa mainly due to the thermal degradation of the high sugar content and secondly, to the subsequent formation of some powerful

odors through the Maillard reaction (Sahin et al. 2009). Carcao is used in the confectionery industry as a substitute for cocoa for a number of reasons including its being cheaper than cocoa. It is also very low in fat and sodium and, unlike cocoa, has almost no caffeine (Akdeniz et al., 2021; Lanfranchi et al., 2019; Loullis et al., 2018). The replacement of cocoa flour with carob flour has been shown to bring significant advantages from nutritional and technological points of view. Regarding the nutritional aspects, the chemical composition of cakes produced with carob flour instead of cocoa powder showed a higher content of dietary fiber and a lower content of fats and carbohydrates as well as a lower caloric intake. From a technological point of view, replacing cocoa with carob flour allows for greater yields. Cakes with up to 75% replacement of cocoa powder with carob flour showed no differences in terms of flavor, smell and texture, demonstrating that substitution up to this level does not influence in any way the organoleptic and sensorial characteristics of the final product (Rosa et al., 2015). From these considerations it is possible to consider carob flour as a precious ingredient/additive containing nutritional and bioactive compounds that can be used in food products as a healthier and cheaper alternative to cocoa. This substitution represents a technological solution in the production of innovative, functional and healthier sweets, with less added fat and sugar and a higher fiber content (Testa et al., 2023). Due to all these characteristics, and due to the growing demand for functional foods and also considering the increase in the costs of cocoa, this by-product of the carob industry is considered a potential future ingredient in cocoa-based formulations and as a nutraceutical ingredient in gluten-free products as well as for the production of healthy/functional foods increasingly requested by the market.

The preparation of carob syrup involves the preparation of a mixture of carob pulp and water which is then drained and boiled until the desired consistency. Carob syrup does not contain oils and is rich in sugar (63,88%), mainly fructose, glucose and sucrose (Musa et al., 2007). It has a high presence of minerals (potassium, phosphorus and calcium) and it has a higher level of silver and titanium than carob fruit. These physico-chemical characteristics make carob syrup a functional ingredient (Brasseco et al., 2021).

From the carob pulp it is also possible to produce carob fiber (from 30% to 40 of the pulp) prepared with water extraction and removal of most carbohydrates in carob pulp. In general, carob fiber is insoluble and not fermentable. Production methods of natural carob fiber have also been patented. Carob fiber has a great potential value in prevention and treatment of colorectal cancer, although unfortunately, the literature that directly proves the anti-colon cancer effect of carob fiber is very limited (Zhu et al. 2019). A beneficial role of carob fiber has also been shown in dyslipi-

demia due essentially to the large amount of insoluble dietary fiber (Valero-Munoz et al., 2014; 2017).

Thanks to its intrinsic health-promoting qualities, carob fiber can be used as a functional ingredient in a wide range of foods (baked products, health bars, extruded products, milk-based drinks and dietary supplements). It has been shown that carob fiber added to food products helps, without causing adverse reactions, to significantly reduce plasma cholesterol levels, especially LDL cholesterol. Furthermore, carob fiber has a substantial amount of insoluble and water-soluble polyphenols with antioxidant potential with positive health effects. The antioxidant activity of carob fiber in food products also helps to improve the shelf life of products (Haber, 2002).

3 Applications of seed flour in the food and pharmaceutical industries

Locust bean seeds consist of the epiperme or external film (30-33% by weight), endosperm or gum (42-46 %) and germ (23-25 %). The most important part of the seed is endosperm, which is very rich in galactomanan that is a polysaccharide molecule composed of mannose and galactose sugar units. This product is known as Locust Bean Gum (LBG) and is used in the food industry as a stabilizing and thickening additive. Seeds are difficult to process, as their coating is very hard. The seeds are peeled without damaging the endosperm and embryos (germs). After the peeling process, the endosperm can be divided from the cotyledons because of their different friability. After the cleavage process, the endosperm is ground on roller mills to the desired particle size to produce LBG and carob germ flour that is a by-product of seed processing (Karababa et al., 2013). LBG is included in the positive list of additives authorized in the European Union (code E 410) and has the characteristic of having high stability at high temperatures. This makes this product useful for many applications in the food industry. Its acceptable daily intake is unlimited because the results of biochemical, toxicological and nutritional studies have shown that it does not present any risk to human health (EFSA, 2017). Commercial application of carob bean gum in the food industry is in the preparation of ice cream, sauces and condiments, frozen products, dairy products and meat products. LBG is used as a food ingredient for its stabilizing and thickening properties and to improve the gel quality of other hydrocolloids. For example, in the manufacturing of low-fat dairy products LBG allows them to maintain a desirable body structure, in the manufacturing of infant formula it increases the viscosity of the milk, in the manufacturing of baked products LBG allows for the production of higher yields of baked products, improves the final

consistency and gives the dough more viscosity (Nasrallah et al., 2023). LGB consists of viscous soluble fibers, capable of modifying the speed of carbohydrate degradation during digestion with beneficial effects on the regulation of postprandial blood sugar and insulin levels, favoring the prevention of obesity and diabetes. LGB may also be useful for the control of inflammatory bowel disease, Crohn's disease and ulcerative colitis (Barak, 2014). Moreover, LBG can be used in the production of edible and biodegradable films/coatings. The demand for these types of packaging is increasing in the food supply chains in order to improve the shelf life of fresh products such as fruit, vegetables and meat as a replacement for plastic packaging. LBG has hydrophilic properties that allow it to produce films with carbon dioxide permeability, oxygen permeability, water vapor permeability, tensile strength and elongation-at-break under certain conditions. LBG edible films can also serve as a carrier of bioactive additives and components (Singh et al., 2022).

Carob germ flour, a by-product of seed processing, has a high protein content, with a high content of lysine and arginine as well as a high presence of dietary fibers and micronutrients. It can potentially be used both as a protein supplement in food preparations and as an ingredient in cereal-based products for people with celiac disease (Saitta et al, 2023). In addition, carob seed flour is used in the textile and paper industries as thickening material for printing (Barak et al., 2014). In the pharmaceutical sector it is used as a binder and disintegrator for tablets and pills, and in many other applications that are being studied in biopharmaceutical industry (Dionisio et al., 2012).

4 Evolutionary trend of carob cultivated area and production

Data analysis focused on the evolution of carob production over time shows a marked decline in interest in this promising crop, which resulted in a significant decrease in cultivated areas and consequently in carob bean production. In fact, from the available data, since the 60s to the present, there has been a decline in both carob production and carob cultivated areas of about 93% worldwide Figure 2 and 3 (FOASTAT, 2023).



Figure 2 – Historical series and average trend of carob production in the world and in Italy



Figure 3 – Historical series and average trend of carob cultivated area in the world and in Italy

Global seed production for the four-year period 2019-2022 varied between 25 and 30 thousand tons, distributed among the producing countries according to the percentages indicated in Figure 4 (ISMEA, 2023).

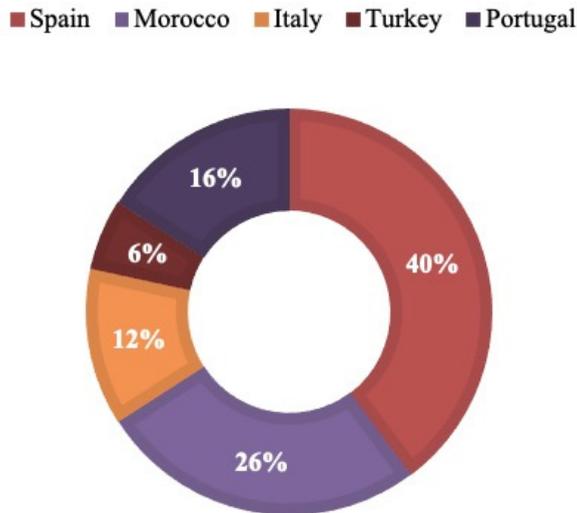


Figure 4 – Percentage of carob seed production per country for the four-year period 2019-2022 at a global level

It is confirmed that the countries with the greatest share of carob production are those in the Mediterranean area, where the Arabs spread the cultivation beginning in the medieval period, mainly in certain regions and well-defined areas where the cultivation of carobs gives a characteristic territorial aspect. However, the decline in carob production, though widespread, has not equally affected all geographic areas devoted to the production of locust beans, and Italy is the country that has been the most resilient with a 67% decrease in cultivated area and a 73% decrease in production Figure 2 and 3 (FAOSTAT, 2023).

Although they are in decline, the main carob cultivated areas in Italy are in Sicily, representing more than 98% of the total carob cultivated area (Table 1), specifically concentrated in the provinces of Ragusa and Siracusa. The second Italian region in terms of carob cultivated area is Apulia, representing less than 2% of the total. In this region carob cultivation could be a valid alternative to regenerate the Salento area (Southern Apulia Region) affected by the *Xylella fastidiosa* outbreak which hit olive groves and to overcome an agricultural system based on monoculture (De Boni et al., 2022).

	2018		2022	
	ha	%	ha	%
Sicily	5.465	98,01	5.415	98,2
Apulia	109	1,95	99	1,8
Lazio	2	0,04	—	—
ITALY	5.576		5.514	

Table 1 – Carob cultivated area in Italy (2018-2022)

Italy has reached a leading position in carob production that until the 90s was occupied by Spain. The Italian average carob production in the last 5 years was approximately 35 million kg per year. As shown in Figure 5, the Italian carob production in 2022 was 356,185 quintals distributed between Sicily (98.5%) and Puglia (1.5%) (ISTAT, 2023).

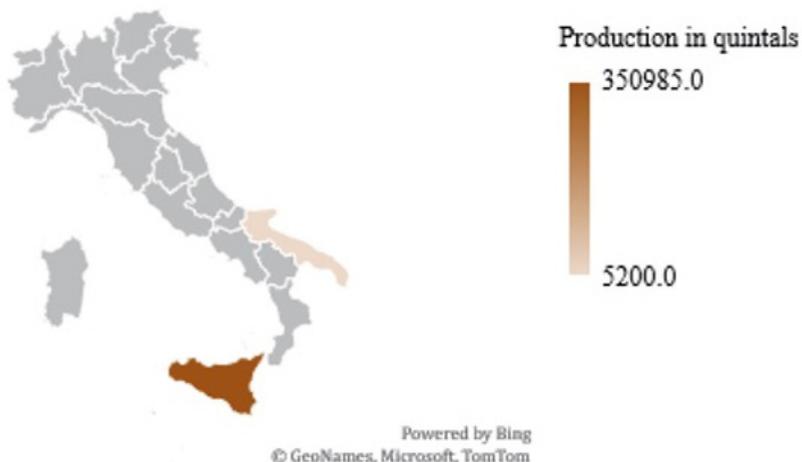


Figure 5 – Regional distribution of carob production in Italy

The cultivation of the carob trees, the production, transformation and marketing of the fruits, seeds and their derivatives are typical economic activities of the Iblean plateau area, in South-Eastern Sicily, which involves the agricultural and livestock sectors, but also the transformation and commercial ones.

The cultivars are *Latinissima*, *Saccarata*, *Racemosa*, *Falcata*, *Ibla*, *Pasta*, *Ruta* and *Tantillo*; among these the *Latinissima* is the most widespread. However, among the most common Italian varieties, a high level of heterogeneity regarding the size and weight of the pod has been observed, as well as the weight and number of the seeds contained in the pod. In particular the pods of *Pasta* are those with the greatest length and together with the *Ruta* are heavier than others. The cultivars *Pasta* and *Ruta* showed the heavier seeds and *Pasta* also showed a higher number of seeds produced. *Ibla* has the highest yield of seeds in terms of seed weight in relation to the weight of the pulp of the pods collected (La Malfa & La Rosa, 2006; La Malfa et al., 2010).

5 Discussions

Since rural areas are periodically subject to significant shocks with heavy environmental, economic and social repercussions, developing useful solutions aimed at ensuring the continuity of the agricultural and agro-industrial systems, the resilience and/or the regeneration of these areas, represents a fundamental need for local communities.

The present study highlights the potentials of carob tree cultivation, as a solution to regenerate marginal areas or areas affected by shocks, ensuring the continuity of the agricultural sector, creating a profitable chain for farmers, which is also virtuous because it is oriented towards the conservation and protection of rural areas, as well as the disincentive of passive farm income.

Recently, after a period of lack of interest in the carob cultivation in Italy, as in other producing countries, there has been greater attention paid to this crop which stems above all from the price response, which, in Italy, has occasionally recorded peaks even higher than 2 euro/kg. All this certainly derives from the international market values of carob seeds intended for rubber extraction. This conjuncture has also led to an increase in the cost of carob seed flour and has recently triggered a reduction in demand (ISMEA, 2023).

Thus, the potential profitability of the carob tree cultivation depends on the valorization of the fruit and seed by the processing industry, to be used to obtain products and by-products aimed above all at the

human and animal food industries; the ease of carob tree agronomic management, resulting from the rusticity characteristics of the species; and the opportunity for expansion into marginal areas.

6 Conclusions

In the past, carobs have mainly been food for livestock and, in periods of reduced availability of food, also a source of energy for people in the Mediterranean region who eat carobs and discard the seeds. Nowadays, carob pulp and beans have the potential to be used to produce high value-added goods.

Carob pulp can be considered a valuable additive usable in food-stuffs as a healthier and cheaper alternative to cocoa. This substitution represents an agro-technological solution for the development of innovative, functional and healthier confectionery, with less fat and added sugar and a higher fiber content.

Also, the seed, whose flour is known as LBG, is of great interest and is rich in galactomannans, highly valued in the food industry for its properties as a thickener, emulsifier, stabilizer and natural gelling agent, as well as in the pharmaceutical and paper industries.

These multiple interests in all parts of the carob require great research efforts related to the selection of species which have a useful pulp/seed ratio according to the different applications. Today the focus is mainly on seedlings with a high yield in seed at the expense of the yield in pulp.

The study represents a preliminary step for the development and enhancement of an innovative agri-food supply chain related to a secular forestry crop, which can develop high potential in terms of industrial use and added value, preserving and promoting preserving and promoting the territory. In addition, the cultivation of *Ceratonia siliqua* L. trees in regions with a Mediterranean climate, with scarce natural resources, will result in the preservation and recovery of the ecosystem services provided by the rural areas, avoiding their marginality and allowing for their regeneration from an economic, environmental and social perspective.

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Il volume presenta gli Atti del Convegno dell'Associazione Italiana di Scienze Merceologiche, in tema di "Qualità, Innovazione e Sostenibilità nella filiera agro-alimentare: il contributo delle Scienze Merceologiche". Esso raccoglie interessanti contributi scientifici relativi al settore agro-alimentare a cura di ricercatori e professori del settore delle Scienze Merceologiche che indagano strategie innovative per migliorare la sicurezza alimentare, ridurre l'impatto ambientale e promuovere modelli di produzione e consumo responsabili, attraverso un approccio multidisciplinare e rigoroso. I contributi arricchiscono il dibattito scientifico sul tema fornendo interessanti spunti di riflessione per policy maker, imprese e stakeholder nella costruzione di un sistema alimentare più equo, sano e sostenibile. Attraverso questo volume le Scienze Merceologiche consolidano il loro ruolo di punto di riferimento nel panorama nazionale, contribuendo ad accrescere la conoscenza e lo studio di modelli, metodi e approcci volti a garantire qualità, innovazione e sostenibilità lungo l'intera filiera agro-alimentare.

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