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Yield and composition of carob bean gum produced from different Moroccan populations of carob *(Ceratonia siliqua L.)*

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Abstract
The carob product most widely used, especially for the food industry, is the carob bean gum (CBG), or locust bean gum (LBG). This gum comes from the endosperm of the seed and chemically is a polysaccharide, a galactomannan. It is used as thickener, stabilizer, emulsifier and gelling agent. This study was carried out to determine and to compare the characteristics of LBG in terms of yield, moisture and ash content and protein content. Samples were collected from different regions in the agro-forestry system of Morocco. The results showed that the Moroccan cultivars are characterized by a high yield of seeds that provide a high yield of endosperm. The purified CBG from different population of Moroccan carob tree had 60.63–72.49% yield, 6.36–8.63% moisture, 0.36–0.99% ash and 0.52–0.62% protein. The protein, moisture and ash, and the yields of purified locust bean gum are comparable to those reported in the literature from other countries.

Keywords: Carob pulp; Carob seeds; Carob bean gum; yield; Composition.

1. Introduction
Carob (*Ceratonia siliqua* L.) is a typical tree of the semiarid environments in the Mediterranean area. This species belongs to the subfamily Caesalpinioideae of the Leguminosae family [1]. It produces edible pods used as a fodder for breeding cattle; it has also a long history of application as a source of health products. World production is estimated at about 315 000 tons per year, produced from about 200 000 hectares with very variable yields depending on the cultivar, region, and farming practices [2] and the main producers for (pulp, seeds) respectively are Spain (36%, 28%), Morocco (24%, 38%), Italy (10%, 8%), Portugal (10%, 8%), Greece (8%, 6%), Turkey (4%, 6%) and Cyprus (3%, 2%) [3].
The carob distribution in Morocco is centred in the north selvage of the Atlas chain, the Rif Mountain and in some valleys of the South-West of the Anti-Atlas confined to arid and semi-arid bioclimates with an extension to sub-humid bioclimate in some stands [4].
Chemical composition of the carob pod depends on cultivar, origin and harvesting time [5]. The two main carob pod constituents are pulp (90%) and seeds (10%) by weight [6]. Carob pulp is high (48–56%) in total sugar content that include mainly sucrose, glucose, fructose and maltose. In addition it contains about 18% cellulose and hemicelluloses, (3–4%) protein and (0.4–0.8%) lipids [7]. Also, ripe carob pods contain a large amount of condensed tannins (16–20%, d.b.). The pulp of carob pods is used extensively as a raw material for the production of syrups [8,9] and crystallized sucrose for the food industry. On the other hand, carob seed constituents are seed coat (23–33%), endosperm (42–56%) and embryo (20–25%) by weight [10].
Nowadays, carob is exploited prevalently for the industrial transformation of the seeds, for obtaining flour called carob bean gum (CBG), used as thickening agent in food preparations [7]. The European Codex classifies CBG as a fully accepted food additive for human use (E 410).
Carob bean gum (CBG), is the refined endosperm of the seed of the carob pods (*Ceratonia siliqua*) by extraction of the seeds with water or aqueous alkaline solutions. The extraction of the gum from the seeds is a slow, difficult process, due principally to the hardness of the seed coat. Different mechanical, physical and chemical methods have been studied for the removal of the seed coat and for separating the coat, the endosperm (gum) and the cotyledons [11, 12]. CBG is a galactomannan composed of a linear chain 1→4 linked β-D-mannopyranosyl units, with α-D-galactopyranosyl residues 1→6 joined as irregularly spaced side chain [13].

Featuring different physicochemical properties, CBG is a versatile material used for many applications: they are excellent stiffeners and stabilizers of emulsions, and the absence of toxicity allows their use in the textile, pharmaceutical, biomedical, cosmetics, nutrition sciences, and food industries [14, 15, 16, 17, 18].

An important application of this biopolymer is its ability to form very viscous solution at relatively low concentration, to stabilize dispersion and emulsion and to replace fat in many dairy products. Carob gum properties are generally unaffected by pH, salts, or heat processing because it is non-ionic [19, 20]. It is also compatible with other gums and thickening agents (carraghenan, agar, xanthan) to form a more elastic and stronger gel [21].These properties of CBG allow its use as interesting additives for several industries, in particular for the food industry.

Therefore, the purpose of this study is to identify rich gum carob provenance in the agro-forestry system of Morocco (Figure 1) to be use for industrial carob bean gum extraction.

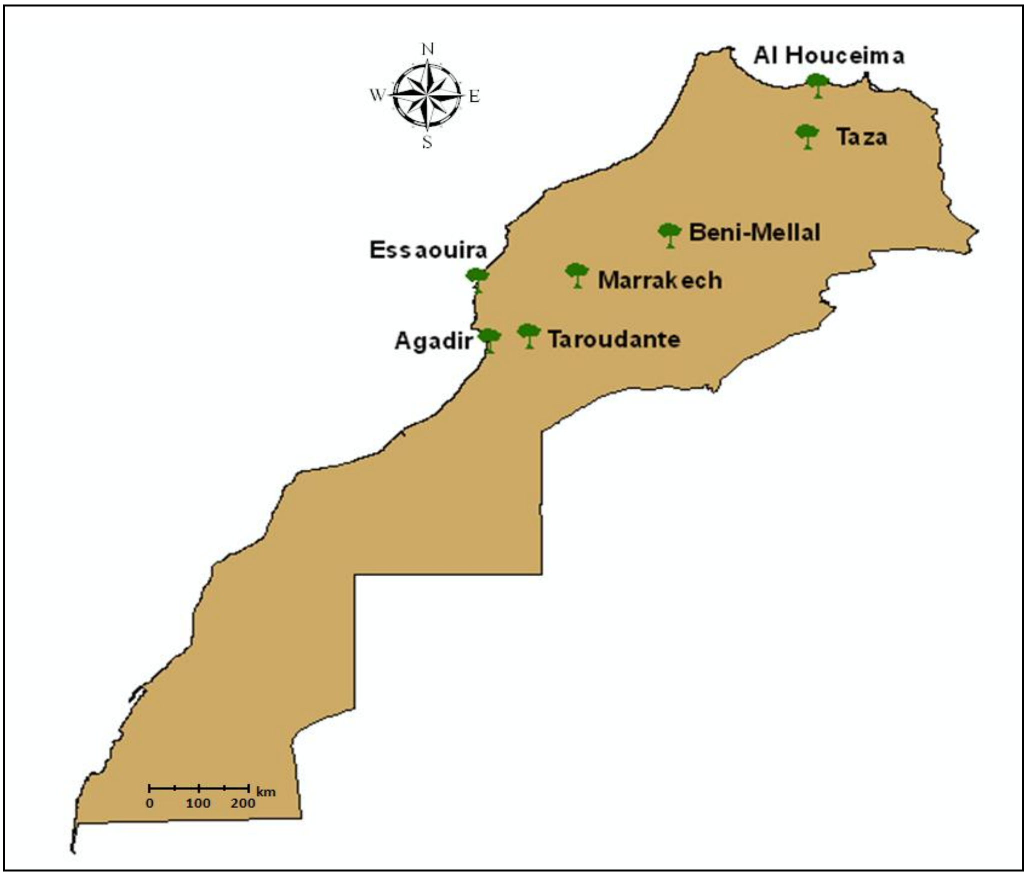

Figure 1. Repartition map of Moroccan populations of carob

2. Materials and methods

2.1. Selection and preparation of samples

The material collection was carried out during summer. For each provenance (Figure 1), 30 trees were randomly chosen for collection of composite samples. These later were characterized according to the following morphological parameters: pods weight, seed yield and pulp yield.

2.2. Extraction procedure:

Figure 2 show the extraction and purification processes used in this work to obtain the purified CBG. The seeds are dehusked by treating the kernels with thermal mechanical treatments, followed by milling and screening of the peeled seeds to obtain the endosperm (native carob bean gum). The pretreated dry powder of crude carob bean gum CBG was extracted with distilled water (ratio of water to endosperm of seeds (197:1), temperature of the water bath 97°C, for a given time (extraction time 36 min).

The solution and the solid-phase were separated by centrifugation at (21875rpm, 1h). The Carob Bean Gum is precipitated with one volume excess of isopropanol. The white fibrous precipitate formed was collected by filtration with screen 45µm, and washed twice with isopropanol and with acetone. After drying under vacuum overnight at 30°C, the precipitate was ground to a fine powder.

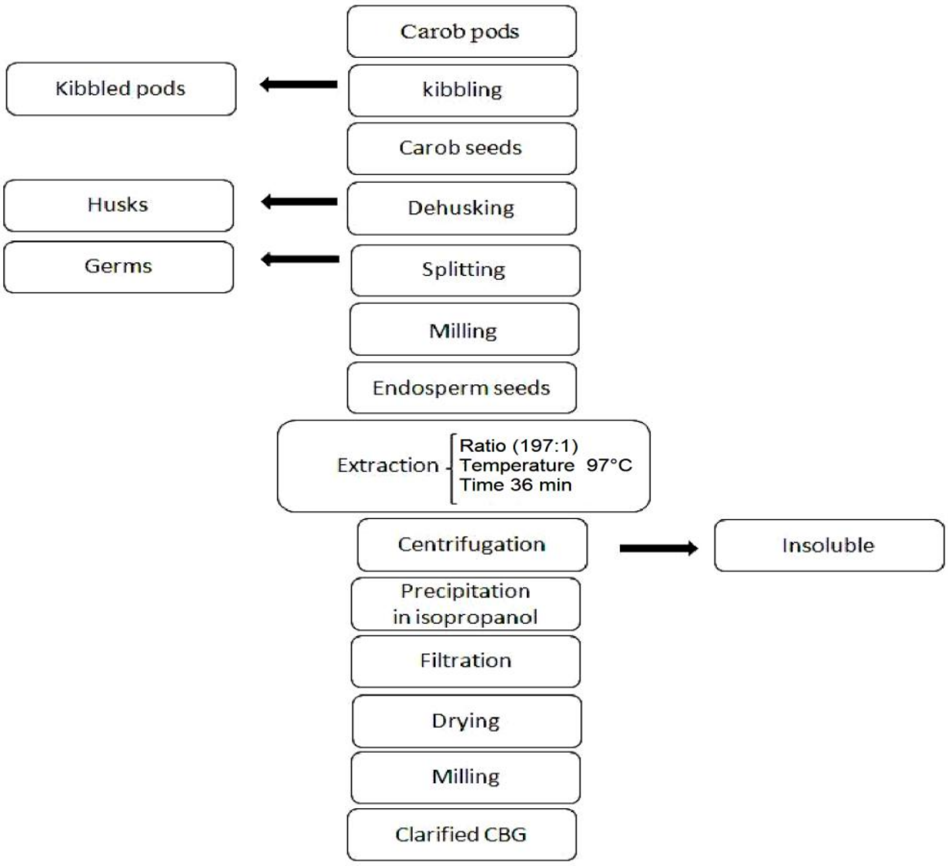

Figure 2. Extraction and purification process of carob been gum.

2.3. Chemical composition:

Moisture and ash content were determined according to the AOAC methods [22]. Total nitrogen was determined by the Kjeldahl modified method; a conversion factor of 6.25 was used to obtain the protein content [23].

3. Results and discussion

This work was carried out on different geographic regions of carob trees in agro-forestry systems. Climatic data were analyzed all over Morocco, a stratified sampling method was used in which topography, vegetation homogeneity and altitude were regrouped in 7 geographic entities (Figure 1). Each entity (provenance) is here defined as a region characterized by similar topographic and climatic conditions with a homogeneous flora. Geographic characteristics such as altitude slice, central latitude and longitude as well as the mean precipitation of these provenances are summarized in Table 1.

Table 1. Geographic and meteorological conditions of provenance of carob.

Provenance	Geographic region	Latitude	Longitude	Altitude	Rainfall
Taroudant	High Atlas (South-West)	30°37’	8°20’	200-400	250
Agadir	West costal	30°41’	9°33’	150-350	300
Taroudant	-	31°20’	9°40’	100-200	300
Marrakech	High Atlas mountain	31°29’	7°43’	700-1000	500
Beni Mellal	Middle Atlas mountain	32°30’	6°03’	500-800	550
Taza	-	34°08’	4°08’	500-600	700
El Houceima	North-costal	35°11’	3°57’	50-250	327

3.1. Measurement of carob pods

Results of carob pod measurements are shown in Figure 3. The overall mean values for all parameters measured and their standard deviations are presented. High levels of variation were found considering the 7 provenance studied. The data from this study showed that there were no significant differences (P>0.05) among the seven crops as far as yield of pulp and seeds is concerned (Figure 3).

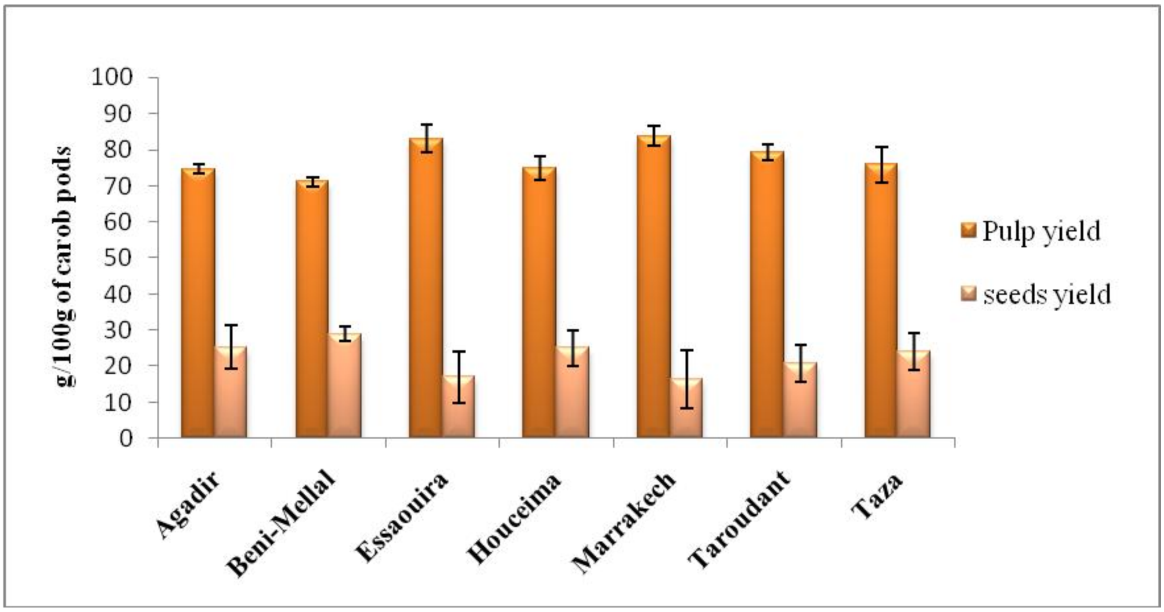

Figure 3. Yield of pulp and seeds of carobs pods from different provenances

Data obtained from other studies (Table 2) showed a high diversity in the yield of pulp and seeds of carob. Moroccan crops are largely characterized by high seeds yield average [17.47-29.44%] content and medium pulp yield average [71.30-82.30%]. Spanish, Tunisian, Portuguese and Turkey crops produce low to medium seeds yield and medium to high pulp yield [24, 25, 1, 26**]**. The results obtained in this study, however, were in agreement with the literature.

Table 2. Measurement average of carob in this study and from other studies

Country	Seed Yield	Pulp Yield
Morocco (present work)	17.47-29.44	71.30-82.30
Portugal [25]	12.00-14.00	86.00-88.00
Tunisia [26]	13.00-18.00	82.00-87.00
Spain [24]	7.00-16.00	84.00-93.00
Turkey [1]	10.02-17.77	82.23-89.98

3.2. Comparison of samples from different carob tree populations in Morocco:
Results of carob seeds yield are shown in Table 3. High variation was found considering the 7 provenances studied. The seeds yield ranged from 19.81% to 29.44% for *El houseima* and *Taza* respectively. Data obtained from other studies showed a high diversity in the yield of carob seeds.

Table 3. Yields of seeds, endosperm and purified CBG from seven different carob samples.

Provenance	Seeds yield (g/100g of Carob pods)	Endosperm yield (g/100g of seeds)	CBG Yield	
			(g/100 g of dry	(g/100 of seeds)
Taroudannt	23.04±7.56	54.24± 0.62	72.50±2.12	40.05±4.02
Agadir	23.33±6.75	50.76 ±1.39	65.47±1.03	34.55±5.46
Essaouira	21.49±7.72	57.40± 2.30	65.73±2.86	39.38±4.94
Marrakech	26.13±8.08	54.15± 1.70	68.97±1.77	38.03±4.98
Beni Mellal	25.06±6.55	57.00± 1.67	61.91±1.79	36.59±5.53
Taza	29.44±5.60	54.28± 1.12	62.78±1.55	35.70±6.19
El Hoceima	19.81±5.28	55.07± 0.07	60.63±1.44	34.65±6.43

Moroccan cultivars are largely characterized by high seeds yield. Portuguese cultivars produce from 12.00 to 14.00% [25], Tunisian: 13.00 to 18.00% [26], Spanish: 7.00 to 16.00% [24] and Turkish: 10.02 to 17.77 [1]. The separation of the seed components furnished a higher yield of yellowish endosperm: 50.76-57.40 g per 100 grams of seed.
The obtained purified gum is a white to yellowish white, nearly odorless powder. The mean value of CBG yield varied from 60.63 to 72.49 g per 100 grams of dry endosperm and from 34.55 to 40.05 g per 100 grams of seeds in the samples from *El Hoceima and Taroudannt* respectively. Battle [27] reported that by weight, about a third of the seed consists of gum. In Cyprus carob, one hundred kg of seeds yields an average of 20 kg of pure dry gum [28].
Moisture, ash and protein contents of the purified carob bean gum are shown in Table 4. There are significant differences in the contents between the analyzed samples. The amounts of Moisture varied between 6.44 and 8.63 %, Ash varied between 0.36 and 0.99 % and protein varied between 0.54 and 0.62 %. In the literature, Kawamura [29] reported that the samples of Italian clarified carob bean gum contain approximately 3-10% moisture, 0.1-1% ash, and 0.1-0.7% protein. The purified CBG from seven areas of the north and centre of Tunisia had 3.43–6.99% moisture, 0.87–2.06% ash, and 0.61–2.46% protein [30].

Table 4. Compositions of CBG from seven different carob samples

Provenance	Composition in g/100g of CBG		
	Moisture	Ash	Protein
Taroudannt	7.05±1.15	0.68±0.03	0.62±1.30
Agadir	6.85±0.14	0.59±0.02	0.59±0.41
Essaouira	7.47±0.37	0.64±0.02	0.55±0.77
Marrakech	8.63±0.53	0.99±0.01	0.52±0.73
Beni Mellal	6.36±0.31	0.36±0.00	0.55±0.39
Taza	6.44±0.62	0.66±0.04	0.56±1.19
El Hoceima	6.44±0.62	0.77±0.03	0.54±0.38

Conclusion

The proportions of carob pulp and seeds, the yield and the composition of CBG show a great diversity between the populations of the Moroccan carob tree. This diversity seems to take place according to the geographical origin of the population. The obtained results are comparable with those reported in other studies for crops of various origins.
The obtained CBG yield ranging between 34 and 40 g per 100g of seeds are very interesting for industrial exploitation. According to this study, the most interesting samples for extraction of high CBG yield are those collected in the region of *Taroudant*, *Essaouira* and *Marrakech.*

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