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RESEARCHARTICLE

VARIABILITY IN PHYSICOCHEMICAL AND NUTRITIONAL PROPERTIES OF GUM FROM *COMBRETUM NIGRICANS* LEPR. EX GUILL. & PERR. FROM THREE CLIMATIC ZONES OF BURKINA FASO

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ABSTRACT

In Burkina Faso, the consumption and marketing of Non-Timber Forest Products (NTFPs) contribute to food security and the well-being of the population. It is therefore important to develop valorization strategies that will promote sustainable management of species providing these NTFPs. The objectives of this study were to (i) contribute to a better knowledge of the physicochemical properties of gum from *Combretum nigricans* fom the three climatic zones of Burkina Faso (Sudanian, Sudano-Sahelian and Sahelian zones) and (ii) assess the nutritional value of this gum. The gum was harvested from different trees in nature reserves and then, for each climatic zone, a composite sample was taken for laboratory analysis. Analyses included moisture content, pH, ash content, nitrogen and protein contents, mineral content, total sugar content, fat content and secondary metabolite content (total polyphenols and total flavonoids). Results showed that climate significantly influences the physicochemical properties of *C. nigricans* gum. This gum has properties similar to those of gum arabic. It is mainly composed of carbohydrates and contains high rates of potassium, calcium and magnesium. *C. nigricans* gum has interesting nutritional properties and can therefore be used for food, commercial or industrial purposes.

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INTRODUCTION

In Burkina Faso, the valorization of NTFPs greatly contribute to the well-being of the population (UICN-Burkina Faso, 2015). Rational exploitation of these products thus promotes biodiversity conservation, combats desertification, and contributes to strengthening the resilience of households that depend on them (Ky, 2010 ; Elhadji Seybou *et al.,* 2016). However, the species that provide these NTFPs and their habitats are increasingly affected by anthropogenic pressures and climate change (Nacoulma *et al.,* 2011 ; Ouédraogo, 2021). The range of NTFPs exploited in Burkina Faso includes plant gum, which is an exudate obtained from many indigenous species (Poda *et al.,* 2009 ; Ki, 2023). Managing woodlands for gum production could thus be an economically more profitable alternative than timber harvesting or clearing for subsistence agriculture (FAO, 2010). In most sahelian countries, it is recognized that gum production contributes significantly to poverty reduction through the creation of jobs for rural people in the dry season (Shackleton & Shackleton, 2004). Plant gum is an organic substance obtained by exudation from the fruits, trunk and/or branches of trees, either spontaneously or after mechanical injury to the plant. In contact with air, this exudate hardens and form glassy mass (Ahmed *et al.,* 2009 ; Ki *et al.,* 2025). Gum quality can be affected by botanical origin, individual differences between trees, tree age, climatic conditions, soil types and post-harvest handling (Chikamai & Banks, 1993 ; Tahir *et al.,* 2007 ; Eltayeib & Abdelrahman, 2017). Gum Arabic obtained from *Senegalia senegal* (L.) Britton is the most widely used type of gum due to its good properties (FAO, 1990). However, other types of gums can be used as substitute for gum arabic after studying their physicochemical properties (Taha *et al.,* 2012). In Burkina Faso, one of the species exploited for its gum is *C. nigricans*, a species of the Combretaceae family (Ki, 2023). The gum of *C. nigricans* is sold in local markets and used for various purposes (Ki *et al.,* 2022). It is used in the manufacture of ink and paint, in plastering, in fabric starching, etc. In traditional pharmacopoeia, it is used to treat various illnesses such as dysentery, flatulence, gastric ulcers, colds, coughs, toothaches, wounds, etc (Poda *et al.,* 2009; Ki *et al.,* 2022). With an average annual gum production of 214.88 g (Ki *et al.,* 2025) and a wide distribution area in Burkina Faso (Thiombiano *et al.,* 2006), *C. nigricans* could be profitably exploited for the benefit of local populations. Moreover, the gum from *C. nigricans* is edible. However, little is known about the physicochemical properties of this exudate, hindering optimal exploitation of the available potential. The objectives of this study are to :

- determine the physicochemical properties of *C. nigricans* gum from the three climatic zones of Burkina Faso (Sudanian, Sudano-Sahelian and Sahelian zones);
- assess the nutritional value of this gum.

MATERIALS ET METHODS

Sample collection and preparation: In each climatic zone (Sudanian, Sudano-Sahelian and Sahelian), gum was collected from several trees in nature reserves. Before to the analysis phase, the different gum samples from each climatic zone were dried in the laboratory at room temperature (around 30°C) and cleaned to remove all impurities. A composite sample of gum from each climatic zone was taken and ground into a fine powder using a mortar and pestle. The powders were then sieved through a 0.4 mm mesh sieve and stored in labelled plastic jars for analysis.

Physicochemical analysis

Moisture content: Moisture content is obtained according to the AOAC (1990) method. For each sample, three grams (03 g) of gum powder were introduced into a porcelain crucible of mass M_0 and the total mass (crucible + sample) was then determined (M_1). The crucibles were then placed in a dry oven at 105°C for 24 hours. After removal from the oven, the crucibles were cooled in a desiccator and then weighed again (M_2). Moisture content was determined using the following formula:

$$moisture\ \% = \frac{(M_2 - M_0)}{(M_1 - M_0)} \times 100$$

M_0 = mass of the empty crucible ;
M_1 = (crucible mass + sample) before steaming ;
M_2 = (mass of crucible + sample) after steaming.

Ash content: Ash content is obtained according to the AOAC (1990) method. By this method, three grams (03 g) of gum powder introduced into porcelain crucibles were dried at 105°C for 24 hours, then incinerated in a muffle furnace at a temperature of 550°C for 5 hours. Ash content was calculated using the following formula:

$$\%\ Ash = \frac{(M_3 - M_1)}{(M_2 - M_1)} \times 100$$

M_1 = mass of the empty crucible ;
M_2 = mass of crucible plus sample dried at 105°C ;
M_3 = mass of the whole (crucible + ash) after incineration.

pH determination: pH determination consisted of preparing a 5% (w/v) gum solution, calibrating the pH meter with a standard solution of known pH and reading the pH measurement of the gum solution from the instrument.

Mineral content: Ash was prepared from the different gum samples and dissolved in 2N hydrochloric acid. The resulting solutions were then used for mineral determination. Potassium (K) and calcium (Ca) were determined using a JENWAY PFP7 flame spectrometer, while magnesium (Mg) was determined by complexometry using ethylene diamine tetraacetic acid (EDTA). Phosphorus was determined using the colorimetric method with a UV visible spectrophotometer at 720 nm.

Nitrogen and protein contents: Protein determination was done according to the AOAC (1990) method using a Kjeldahl distiller. This method is based on the determination of total nitrogen, which is then converted to protein content and consists of three steps: Sulphuric mineralisation (Digestion), distillation and titration with hydrochloric acid. In the first step, 0.25 g of gum sample was introduced into Kjeldahl matras. To these tubes were added 10 ml of sulphuric acid at 98% and a pinch (1 g) of copper sulphate pellets was used as catalyst. Potassium sulphate (l g) was added to raise the boiling point of the sulphuric acid. The mixture was introduced into a digester and digestion is carried out at 340°C for 3 hours. To this mixture was added 50 ml of soda (40%). The whole mixture was placed in the distillation unit. The distillate is recovered in 30 ml boric acid (2%) in the presence of a mixed colour indicator (methyl red + bromocresol green). The change in colouration marks the absorption of total nitrogen. The decolourisation is carried out with 0.1N hydrochloric acid until the colour change. The result obtained after titration allowed us to calculate the percentage of total nitrogen according to the following formula:

$$Total\ nitrogen\ content = \frac{V(HCl) \times N(HCl) \times 0{,}014 \times 100}{W}$$

V(HCl) = HCl volume of the burette drop;
N(HCl) = normality of HCl;
0.014 = coefficient assigned to the concentration of the normal nitrogen solution (14/1000);
W = weight of the sample.

$$protein\ content\ =\ nitrogen\ content\ x\ 6.6$$

Total sugars determination: Total sugars were determined according to the method of Dubois *et al.,* (1956). This method consists in adding successively to 200 µL of each extract, 100 µL of phenol at 5% and 500 µL of sulphuric acid at 95.5%, then shaking rapidly. After 10 minutes of rest, the mixture is placed in a water bath at 30°C for 15 minutes after a second shaking; then cooled to 20°C. Absorbances are read at 485 nm using a microplate reader against a blank containing distilled water and reagents except the sample. Total sugars are deduced from the right-hand equation of the glucose and fructose calibration curve established for this purpose. Results are expressed in mg GE/100 mg and mg FE/100 mg.

Fat content: The fat content is determined according to ISO 659 (1998). A test sample of 5 grams (We) of gum powder from each sample is weighed into a paper cartridge. The loaded cartridge, covered with dehydrated cotton, is inserted into the Soxhlet body. The lower part of the body is coupled to a flask containing petroleum ether and the upper part to the refrigerant. The device is gently heated over an electric heater to 60-70°C, during which the solvent vapour in contact with the coolant condenses and then falls drop by drop into the body containing the sample. Once filled, the mixture empties into the flask and the process starts again. The extraction was carried out for 4 hours. The extraction solvent was separated from the fats by evaporation under reduced pressure in the rotavapor. The flask containing the lipids was placed in a dry oven for one hour at 105°C to remove traces of solvent, then placed in a desiccator for about 30 minutes to cool. A series of weighing and drying of the flask is carried out alternately until a constant weight W_f is obtained. The total fat content is expressed as a percentage by weight according to the following formula:

$$Fat\ content\ (\%) = \frac{W_f - W_0}{W_e} X\ 100$$

W_f = Weight of flask after extraction and evaporation of solvent;
W_0 = Weight of empty balloon;
W_e = Weight of the test socket.

Total carbohydrate content: Total carbohydrate content was determined according to the formula described by Bertrand & Thomas (1910):
Total carbohydrates (%) = 100 - (% moisture + % protein + % fat + % ash)

Energy value determination: Energy value was calculated according to the formula of Coleman (1970) using the coefficients of Atwater & Rosa (1899).

E (Kcal/100g) = (4 x % protein) + (4 x % total carbohydrates) + (9 x % fat)

Total phenolics determination: Total polyphenol content was determined by the Folin-Ciocalteu method (Singleton & Rossi, 1965). A standard curve was first made using gallic acid (0 - 100 mg/l). To 50 µL of aqueous extracts, 25 µL of Folin-Ciocalteu reagent at 50% (1N) was added and then 5 min later, 50 µL of Na_2CO_3 solution at 5%was added. The whole set was incubated for 60 minutes. The absorbance was read at 725 nm using a microplate reader. From the reference curve of gallic acid in 95% ethanol, the results are expressed as milligrams of gallic acid equivalent per 100 mg of dry extract (mgGAE/100 mg).

Total flavonoids determination: Flavonoid content of the extracts was determined using the method described by Zhishen *et al.* (1999) and Kim *et al.* (2003) with a few modifications. To 100 µL of extract or quercetin (standard), 100 µL of $AlCl_3$ (2% methanolic solution) was added. After 15 minutes incubation, absorbance is read at 430 nm using a microplate reader. The flavonoid concentration is determined by referring to the calibration curve obtained with quercetin. The results are expressed in milligrams of quercetin equivalent per 100 mg of dry extract (mgQE/100 mg).

Statistical analysis: Each analysis was repeated three times and the values reported were the average of the three replicates. Statistical analysis of the data collected was carried out by an analysis of variance using R4.1.1 software, and Tukey's multiple comparison test was used to compare the means of gum parameters from different climatic zones.

RESULTS

PH: pH of the gum varies significantly ($P < 0.05$) from one climatic zone to another (Figure 1). Analysis of the figure shows that the most acidic gum, i.e. with the lowest pH, is that harvested in the Sudanian zone (pH= 4.05 ± 0.02), while the least acidic gum is that harvested in the Sudano-Sahelian zone (pH= 4.37 ± 0.1). The pH of gum harvested in the Sahelian zone is statistically similar to that of gum harvested in the Sudanian zone, with an average value of 4.15 ± 0.03.

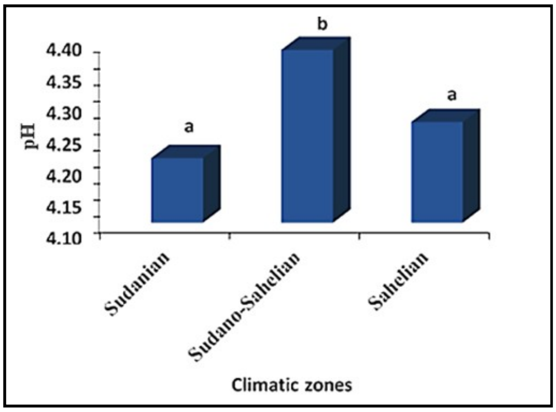

Figure 1. Effect of climate on pH

Moisture content : Figure 2 shows the variation in gum moisture content by climatic zone. The results show that gum from the Sudanian zone has the lowest moisture content, with an average value of 8.94 ± 0.1%. This value is statistically similar to that of gum from the Sudano-Sahelian zone (9.06 ± 0.1%). However, these first two values are significantly lower ($P < 0.001$) than those obtained with gum harvested in the Sahelian zone (11.23 ± 0.1%).

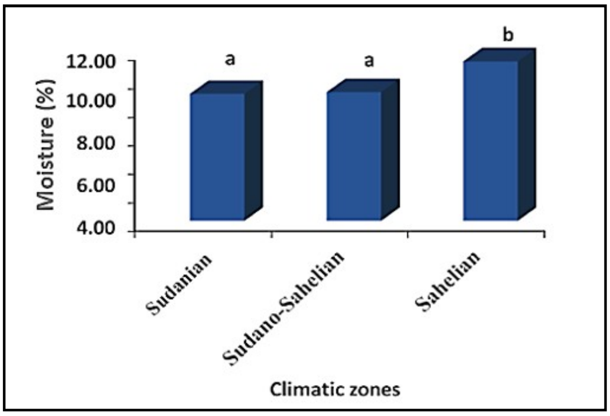

Figure 2. Effect of climate on moisture content

Ash content : Ash content of gum varies significantly from one climatic zone to another ($P < 0.001$) (Figure 3). Gum harvested in the Sahelian zone contains the highest ash content, with an average value of 2.01 ± 0.01%. The ash contents of gums from the Sudanian and Sudano-Sahelian zones are statistically similar, at 1.65 ± 0.05% and 1.63 ± 0.01% respectively.

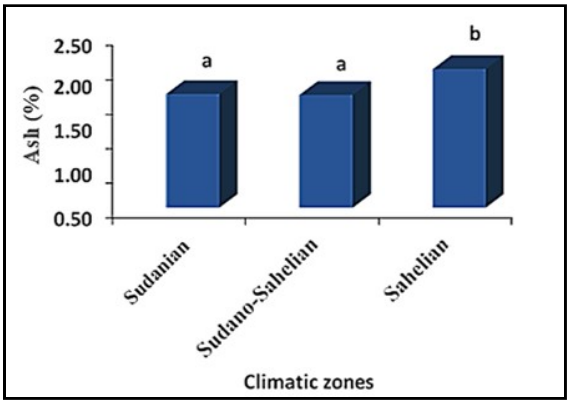

Figure 3. Effect of climate on ash content

Mineral contents : The results of the analysis of variance show that mineral contents vary significantly from one climatic zone to another (P < 0.001). Analysis of figure 4 shows that *C. nigricans* gum is rich in potassium, calcium and magnesium, but low in phosphorus. Gum harvested in the Sahelian zone contains the highest rates of phosphorus (8.74 ± 0.82 mg/kg), potassium (6089.47 ± 94.17 mg/kg) and calcium (5999.22 ± 96.66 mg/kg). Magnesium rates were highest in gums harvested in the Sudanian (3032.94 ± 63.93 mg/kg) and Sudano-Sahelian (3163.83 ± 61.33 mg/kg) zones.

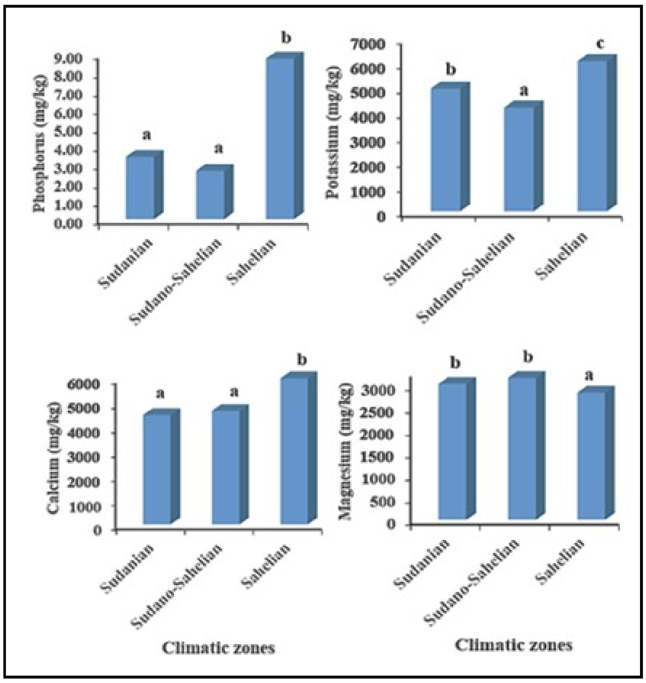

Figure 4. Effect of climate on mineral content (P, K, Ca and Mg)

Total sugars and secondary metabolites: Total sugars, total polyphenols and total flavonoids are shown in Table 1. Total sugar content (glucose and fructose) varies significantly from one climatic zone to another (P < 0.05). For gums harvested in the Sudanian and Sahelian zones, total sugar contents are statistically similar but higher than those obtained with gum from the Sudano-Sahelian zone. In general, the gums harvested are characterized by low polyphenol contents, with statistically similar values ranging from 0.07 mgGAE/ 100 mg (Sudanian and Sahelian zones) to 0.13 ± 0.05 mgGAE/ 100 mg (Sudano-Sahelian zone). However, gum from *C. nigricans* is almost devoid of flavonoids.

Macronutrients content and energy value of gum from *C. nigricans* : The content of the various nutrients used to estimate the energy value of *C. nigricans* gum are shown in Table 2. Analysis of this table shows that climate has a significant influence on carbohydrate and protein contents, as well as on the energy value of gum (P < 0.001). Indeed, the gum with the highest carbohydrate content was harvested in the Sudanian zone, with an average value of 87.84 ± 0.13%. This was followed by gums from the Sudano-Sahelian and Sahelian zones, with values of 87.20 ± 0.1% and 85.71 ± 0.1% respectively. The gum with the highest protein content is that harvested in the Sudano-Sahelian zone (2.22%). Gums harvested in the Sudanian and Sahelian zones contain 1.86% and 1.11% protein respectively. However, we note that *C. nigricans* gum is almost fat-free. The energy value obtained from the different carbohydrate, protein and lipid contents also varies from one climatic zone to another (P < 0.001). It is low for gum harvested in the Sahelian zone (347.05 ± 0.4 Kcal/100 g) and high for gum harvested in the Sudanian (357.65 ± 0.53 Kcal/100 g) and Sudano-Sahelian (357.21 ± 0.4 Kcal/100 g) zones.

DISCUSSION

C. nigricans gum is slightly acidic, with a pH ranging from 4.05 to 4.37. The pH values obtained in our study are very close to those reported for gum arabic from Sudan (pH = 4.4) (Anderson *et al.,* 1990) and Ethiopia (pH = 4.04) (Yebeyen *et al.,* 2009). Gums harvested in different climates vary in moisture content, ranging from 8.94 to 11.23%. These values, lower than those of gum arabic from Ethiopia (15%) and Sudan (13%), nevertheless meet the FAO (1990) specification. Rahimi *et al.* (2013) also noted a variation in the moisture content of gums from individuals of *Amygdalus scoparia* Spach grown in different climatic environments in Iran. Given that the moisture content of a product influences its shelf life (Dussert *et al.,* 2019), the low values found in this study would be an advantage for long-term storage of *C. nigricans* gum. According to FAO (1990) standards, the maximum permissible total ash content for good-quality gum arabic for food and pharmaceutical use is 4.0%. The average ash content of *C. nigricans* gum nodules harvested in different climates varies between 1.63 and 2.01%. These values, although in line with FAO (1990) specifications, remain lower than those reported by Anderson *et al.* (1990) (3.6%) and Yebeyen *et al.* (2009) (3.56%) for gum arabic. The ash content reflects the mineral content of the gum. *C. nigricans* gum has been found to have high concentrations of calcium, potassium and magnesium, which are essential minerals for the body's metabolic needs (Welch & Graham, 2004). Previous studies on *Acacia* gum (Anderson & Morrison, 1989 ; Chikamai & Banks, 1993) have shown that mineral abundance in exudates follows the Ca > K > Mg trend. Our results indicate that only gum collected in the Sudano-Sahelian zone respects this logic. On the other hand, in the Sudanian and Sahelian zones, the order of abundance is reversed between calcium and potassium, with a K > Ca > Mg trend. The mineral composition of gum could therefore either reflect the characteristics of the soil on which the plant has grown (Rahimi *et al.,* 2013), or be strongly influenced by the region of origin (Chikamai & Banks, 1993). The results show that only gums harvested in the Sudanian and Sudano-Sahelian zones contain nitrogen ratess within the limits set by FAO (1990) (0.27 - 0.39). The variations observed could result not only from climatic and soil differences at the collection sitesbut also from genetic differences, since the gum was collected from natural sites. Significant regional variability in the properties of exudates from the same species had already been observed by Mhinzi (2003) in Tanzania. In terms of total sugars, our results indicate a higher glucose content than fructose. However, unlike our study, the majority of research on plant gums (Anderson & Morrison, 1989 ; Chikamai & Banks, 1993) has focused mainly on galactose, arabinose and rhamnose. These studies, which did not provide data on glucose and fructose, identified galactose as the predominant sugar, followed by arabinose and rhamnose. On the other hand, given the low fat content and relatively low protein and ash rates, onecould obviously conclude that carbohydrates are the main component of *C. nigricans* gum. Analyses have also shown that *C. nigricans* gum has an energy value of between 347.05 and 357.65 Kcal/100 g, making it relatively more calorific than the fruits of many local species such as *Detarium*

Table 1. Effect of climate on total sugars and secondary metabolites

Samples	Glucose (mgEG/100 mg)	Fructose (mgEF/100 mg)	Polyphenols (mgGAE/ 100 mg)	Flavonoids (mgQE/ 100 mg)
Sudanian	18.87±0,27a	10.24±0.15a	0.07a	nd
Sudano-Sahellian	17.33±0,6b	9.35±0.32b	0.13±0.05a	nd
Sahelian	18.92±0,2a	10.26±0.11a	0.07±0.01a	-
P-value	**0.003**	**0.003**	**0.09**	

nd : not detected ; －: traces. In each column, values accompanied by different letters are significantly different.

Table 2. Effect of climate on the energy value of *C. nigricans* gum

Samples	Carbohydrates (%)	Nitrogen (%)	Protein (%)	Fat content (%)	Energy value (Kcal/100 g)
Sudanian	87.84 ± 0,13c	0.28b	1.86b	__	357.65 ± 0.53b
Sudano sahelian	87.2 ± 0,1b	0.34c	2.22c	__	357.21 ± 0.4b
Sahelian	85.71 ± 0,1a	0.17a	1.11a	__	347.05 ± 0.41a
P-value	**0.000**	**0.000**	**0.000**		**0.000**

－: Traces. In each column, values accompanied by different letters are significantly different.

microcarpum Guill. & Perr. (299 Kcal/100 g), *Ziziphus mauritiana* Lam. (297 Kcal/100 g) and *Vitellaria paradoxa* C.F. Gaertn. (94 Kcal/100 g (Ministère de la Santé, 2005). Thus, beyond its economic potential as a source of income, *C. nigricans* gum could also contribute to improving the nutritional balance of populations. Our results therefore support those of numerous authors in Burkina Faso and many other African countries (Arbonnier, 2009 ; Ousmane *et al.,* 2017 ; Ki *et al.,* 2022), who have identified *C. nigricans* as a woody food species.

CONCLUSION

The results of this study indicate that climate has a significant influence on the physicochemical properties of *C. nigricans* gum. The data obtained are comparable to those for gum arabic from internationally renowned regions. They also comply with international standards, giving *C. nigricans* gum an interesting commercial potential as a substitute for gum arabic. This gum is also distinguished by its high calcium, potassium and magnesium content, as well as by its high energy value, making it an interesting product from a nutritional point of view. In view of these promising results, it is recommended to promote the silviculture of the species, with particular emphasis on vegetative propagation techniques, with the aim of propagating the most productive individuals and guaranteeing the production of good quality gum.

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