Quality of Gum Arabic in Senegal: Linking the Laboratory Research to the Field Assessment

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Abstract

The objective measurements of quality based on invisible chemical attributes of gum arabic are compared with the assessment done by collectors based on visible attributes with the aim of bringing together the users' quality requirements and the production and marketing practices of collectors. We find that good quality as defined on field is not always good when measured in laboratory; yet such measures can help target different market niches. Moreover, improving quality on field increases the likelihood of obtaining chemically good gum. We also investigate determinants of supply by collectors and traders of two quality attributes namely size and cleanliness of gum nodules. Quality supply is influenced by harvest and post-harvest knowledge and practices, environmental factors and market factors including the behaviour and experience of traders and price.

Keywords: gum arabic, quality attributes, quality measurements, ordered logit, Senegal
JEL: C25, L73, M11, Q13

1 Introduction

Quality is generally defined as a measure of excellence. It is a widely used concept that, however, remains abstract and complex. In production, quality is a state of being free from defects and significant variations, brought about by a strict and consistent adherence to measurable and verifiable standards with the purpose of achieving uniformity of output that satisfies specific user requirements (DALE et al., 1997). In business, quality of goods and services refers to the creation of customer satisfaction and is one of the elements that contribute to profitability (EVANS and LINDSAY, 2005).

Quality has several attributes including intrinsic and extrinsic quality attributes. According to LUNING and MARCELIS (2009), intrinsic quality attributes are objectively and physically linked to the product while extrinsic quality attributes do not necessarily

have a direct relationship with the product properties. They can however affect the users' quality perception or the product's acceptance. Examples of intrinsic attributes include texture, taste, protein content or microbial condition. Examples of extrinsic attributes include religious rules, organic production, or brand name which can subjectively influence the consumers' quality perception or products' acceptance. According to SWINNEN and MAERTENS (2007), these aspects are most pronounced in western markets and urban markets of low-income countries under the description of high quality and safety demands.

Quality aspects are often associated with a cost and a price. The cost of quality means the cost undertaken in the process of improvement including efforts that would not have been expended if quality were perfect (CAMPANELLA, 1999). The price for quality is a premium such that differences in prices of the same product indicate quality differences (TOLLENS and GILBERT, 2003). According to FAFCHAMPS et al. (2008), these differences can even be translated into well-defined grades. Grades are a formalization of the definition of quality of a product so that it has the same meaning for everyone using the product (ABBOTT, 1999). Through grading, producers can choose to supply high quality products in order to access and maintain position in high-value markets and generate higher returns on investments (EVANS and LINDSAY, 2005). Although these high-markets are remunerative, they are also associated with a high risk of rejection. ESCOBAL and CAVERO (2012) indicated that whenever producers cannot meet the quality requirements, they take their products to the 'low-quality' markets where they receive much lower prices due to increased supply in these markets. This risk, in comparison to the large asset base needed to produce and supply high-quality products is the most important factor limiting the adoption of quality standards especially for small producers who are therefore excluded from these high-markets (CHEMNITZ, 2007).

A number of studies linked the quality requirements to the product's acceptability by consumers (HOWLETT et al., 2002; BERNUÉS et al., 2003). These studies focused on the identification of cues that convey information on the quality characteristics of the product. For instance, BERNUÉS et al. (2003) highlighted the importance of extrinsic attributes because they believed that quality characteristics offered by the industry and the quality evaluation that consumers make, depend, not only on the product, but also on the production process. However, relying only on the extrinsic attributes to satisfy consumer's quality requirements was criticised because the relative importance of these attributes differ between consumers with different social, cultural and economic, characteristics (VERBEKE and VIAENE, 1999). Yet, as noted by GRUNERT (2005), producers should be able to translate consumer wishes into physical product characteristics and consumers should be able to infer desired qualities from the way the product has been built. However, consumers are not often especially good at predicting

quality according to GRUNERT (2005) and JAHNS et al. (2001) indicate that their assessment of quality is vague because it just depends on their senses. Therefore the observed increasing dissatisfaction with product quality amongst consumers despite the growing awareness of the importance of product quality by producers may be due to the failure of the existing market systems to communicate quality. It can also be the result of the degrading intrinsic quality as suggested by ZIGGERS and TRIENEKENS (1999). Hence in studies of quality, the importance of both intrinsic and extrinsic attributes should jointly be accepted (ACEBRÓN et al., 2000). In fact, JAHNS et al. (2001) recommend the use of objective measurements for quality assessment with the aim of obtaining measurable factors which can then be compared to the existing quality definitions such that consumers and producers obtain some basic quality standards which can be generally accepted.

We contribute to this quality literature in the context where the user has the ability to make an objective assessment of quality but the producer can only make a subjective assessment. The objective measurements of quality are compared with the assessment done by producers so that the users' criteria of quality can be translated into the production and marketing practices of producers. Taking the case of gum arabic supply, in the first stage, we compare the assessment of quality done by collectors and primary traders through a visual inspection with chemical analysis of the users' criteria that are measurable by laboratory tests. The comparison is done on the basis of clear users' specifications. Next, we examine the current production and marketing practices by empirically analysing determinants of quality supply for two attributes namely the size and cleanliness of gum nodules. Determinants of quality include factors associated with tapping aspects, post-harvest handling and environmental controls as indicated by CHIKAMAI and ODERA (2002). In addition, market factors are also included in the analysis of quality supply. We use a dataset constructed through a monitoring of quality supplied by collectors throughout the gum collection season of 2009-2010 in 16 markets in the sylvopastoral zone and eastern region of Senegal.

In the next two sections, we introduce aspects production, marketing and quality of gum arabic with a special reference to Senegal. These sections are followed by a description of the methodology and subsequently of results. In the last section, we discuss these results, present conclusions and suggest some policy implications and opportunities for future research.

2 Gum Arabic Production and Marketing in Senegal

Acacia trees belong to the botanical family of Leguminosae, a predominant species of the group of Mimosaceae. There are more than two hundred species of *acacias*, but only a few of them produce gums. The only species producing gum arabic, as per FAO

definition, are *Acacia senegal* and *Acacia seyal* which have different properties and are also divided into several varieties: for instance *senegal*, *kerensis, leiorhachis* or *rostrata* for *Acacia senegal* and *fistula* or *seyal* for *Acacia seyal* (FAO, 1971; COSSALTER, 1991; JECFA, 2006). The current research specifically concerns gum arabic as the dried exudate of *Acacia senegal var. senegal*.

Worldwide, Sudan is the largest producer and exporter of gum arabic, followed by Chad and Nigeria, together they bring about 45,000 tons of gum arabic to the market each year (PARTOS, 2009). Senegal, which was once a large producer and exporter of gum arabic, has seen its market share significantly decline over the years: in the late 1950s, Senegal's exports of gum arabic accounted for more than 10 percent of the world exports; it is now in the rank of small producers whose exports totalise less than 5 percent of world exports (FAO, 1971; DEFCCS, 2005; ITC, 2008). Low exports imply low production; hence collectors of gum arabic might fail to improve their livelihoods through incomes that are generated from larger sales of gum. Such livelihoods, in the arid and semi-arid regions where gum arabic is collected, revolve around short annual rains followed by long periods of drought. Economic activities in these regions are pastoralism, small-scale agriculture, and forest exploitation. Pastoralism mainly concerns grazing of animals in a pattern of transhumance while searching for water and pastures. Agriculture is limited by low soil fertility, insufficient water, and declining rainfall (HALL, 2007). Exploitation of timber and non-timber forest products is done with the purpose of labour diversification and consumption smoothing (NGUGI and NYARIKI, 2005). Gum arabic, produced by *Acacia Senegal,* fits into these livelihood strategies: pastoralists use the proceeds from gum sales to rebuild livestock following decimations or thefts; farmers undertake collection of gum to compensate for crop failure; or for consumption smoothing (WICKENS et al., 1995). For producing countries, gum arabic also generates income through its exports thereby contributing to diversification of export products and consolidation of these countries' economies (MBAYE, 1988).

The gum belt in Sudan covers the gross area estimated to cover 520,000 square kilometres which is roughly one fifth of Sudan's total area. This area extends across Central Sudan in 12 states that lie within the low-rainfall savanna zone. The belt covers parts of the clay and sandy plains characterized by a short rainy season of five months with an average rainfall of 300 to 800 mm (ZAROUG, 2006). The gum belt in Senegal covers two production zones which are ecologically comparable to the gum belt of Sudan: the northern sylvopastoral zone (SPZ) commonly called the Ferlo and the agro-sylvopastoral zone also known as eastern Senegal (ES). The sylvopastoral zone is an area of 54,380 square kilometres located at the south of the Senegal River valley covering almost all parts of the regions of Louga, Saint Louis and Matam. Eastern Senegal is an area of 42,706 square kilometres covering the region of Tambacounda

(ANSD, 2010). The sylvopastoral zone is characterised by sandy and clay soils which are fragile and suffer from leaching and erosion (ISRA/BAME, 1999). Eastern Senegal's soil types include sandy-clay soils and rocky soils which are inherently fragile, low in carbon and poor in plants nutrients (DIONE and SALL, 1988; ANSD, 2010). The sylvopastoral zone is characterised by a long dry season of nine months; the average annual cumulated rainfall is between 210 and 520 mm. The rainy season in eastern Senegal is longer, of four to five months; hence the rainfall is a bit higher, between 460 and 680 mm (ANAMS, 2012).

Because of the low and variable rainfall and scarcity of soil nutrients, the sylvopastoral zone and eastern Senegal are characterized by a cyclical insecurity in resource availability (ISRA/BAME, 1999). Collection of non-timber products including gum arabic is practiced for the purpose of generating off-farm income as these products are widely marketed. In marketing, Senegal has followed organisational forms traditionally practiced in colonial times. These forms include private agents acting on behalf of commercial houses, cash transactions and barter exchanges of gum in exchange of other commodities or against advance payments in cash or kind in informal contracts. In the past, the role of the governments was limited to institutional support in terms of regulations which determined the supply chains and fixed commercial norms including prices; currently the gum arabic sector is liberalized (FAO, 1971; DEFCCS, 2005).

3 Aspects of Gum Arabic Quality

Gum arabic is the oldest and the best known of all the natural gums, its uses are dated to about 4,000 years B.C. in inks, paintings, cosmetics, clothing, medicine and mummification process (ALLAND, 1944; CNI, 2008). It was also consumed as food on its own. Gum arabic is currently widely used in food and non-food industries where it functions as an emulsifier, stabilizer, thickener, flavouring or coating agent (WICKENS et al., 1995). These functions are associated with certain quality requirements fulfilled by gum properties such as absorption, tastelessness, odourlessness, solubility, viscosity and rheological behaviour (GLICKSMAN, 1969). Examples of applications of gum arabic in the food industry are shown in Table 1.

Gum arabic is also used in non-food industries for instance in modern pharmacy where it is commonly employed as a demulcent, emulsifier, binder, or for film-forming (KHAN and ABOURASHED, 2010). In addition, gum arabic is used in partial destruction of many alkaloids including atropine, hyoscyamine, scopolamine, homatropine, morphine, apomorphine, cocaine, and physostigmine (KHAN and ABOURASHED, 2010). ALI et al. (2009) suggest a possible use of gum arabic in dentistry because it enhances dental remineralisation and has some antimicrobial activity. Other commercial uses of gum arabic are found in ink production, pottery pigments and glazing for colour

thickening in water-colours and paints, wax polishes or for giving lustre to silk and crepe in textiles and lithography (WICKENS et al., 1995).

Table1. Functions of gum arabic in food products

Function	Examples of food applications
Adhesive	Bakery
Crystallization inhibitor	Sugar syrups, pastilles, candies
Clarifying agent	Beer, wine
Coating agent	Candies
Emulsifier	Caramels, toffees, soft drinks
Encapsulating agent	Powdered fixed flavours
Flocculating agent	Wine
Foam stabilizer	Whipped toppings, beer, marshmallow
Gelling agent	Puddings, desserts, mousses
Mold release agent	Gum drops, jelly candies
Protective colloid	Flavour emulsions (e.g. orange, lime, beer, cola)
Stabiliser	Mayonnaise, beer, ice cream, sherbet
Suspending agent	Chocolate milk
Swelling agent	Processed meat
Syneresis inhibitor	Cheese, frozen foods
Thickening agent	Jams, sauces, gravies
Whipping agent	Icings, toppings

Source: GLICKSMAN (1969), WILLIAMS and PHILLIPS (2009), IDRIS and HADDAD (20012)

Depending on the uses of gum arabic which are as diverse as illustrated above, different quality grades of gum are needed. Typically the food or pharmaceutical industries would require the finest quality whereas the painting or textile industries would not necessarily need the best quality (SOMO, 2009; AGRIGUM, 2011). Quality of gum is determined through an assessment of its attributes. Similar to other products, gum quality possesses both intrinsic and extrinsic attributes. Intrinsic attributes of gum arabic are visible or invisible; they are associated with active structural and physical properties. The visible attributes are the size and fullness or hardness of its nodules, colour and cleanliness; they can be changed intentionally (e.g. through post-harvest cleaning) or unintentionally through the product's interaction with the environment (e.g., as the gum matures or dries, it can change colour). Invisible attributes include gum's chemical composition, these are permanent (LI et al., 2012). Extrinsic attributes of gum arabic include for instance being organically or sustainably collected. Gum arabic is not directly consumed but is just an ingredient in food and non-food processing; hence in its industrial application, the extrinsic attributes are less important than the intrinsic quality aspects.

The visible quality attributes are not only simple indicators of quality applicable under field conditions, they are also important for grading gum by collectors and traders in absence of any more sophisticated method. Grading is important because it helps targeting markets which are undersupplied (MARSHALL et al., 2006). The international market of gum arabic is not well known, hence it is not clear which market niches Senegal targets in its exports. However, it can be implied that as the main buyer of its gum arabic is *Colloïdes Naturels International* (CNI) which is mainly involved in food production, Senegal's gum is generally of sufficiently good quality to be used in the food industries. This corroborates with the findings of CHIKAMAI and ODERA (2002) that Senegal's gum arabic generally has properties which are in the norms of chemical characteristics defined by the Joint FAO/WHO Expert Committee on Food Additives (JECFA)[1]. Senegal's gum shares those characteristics with the exceptional hard gum of Sudan. What is missing in Senegal and in the other small gum producing countries is a known grading system through which quality can be established. Sudan, Nigeria and Chad have registered their gum grades on the world markets such that these grades have become internationally known (e.g. Sudan's grades in Table 2).

Table 2. Sudan classification of gum arabic

Grade	Description	% at sorting
Hand picked Selected	Cleanest, lightest colour, and whole nodule, Ø >30 mm; most expensive grade	0 to 5
Cleaned amber and sifted	Clean and siftings are removed, pale to dark amber colour, whole or broken nodule, Ø >20 mm	5-10
Cleaned	Standard grade, contains siftings but dust is removed, whole nodule plus fragments, 10 <Ø <20 mm	70
Siftings	Fine particles left after sorting, contains sand, bark and dirt, 2.5<Ø < 10 mm	5
Dust	Very fine particles collected after the cleaning process, Ø< 2.5 mm	5
Red gum	Dark and red particles, only for local use	

Ø - Diameter

Source: MACRAE and MERLIN (2002), WILLIAMS and PHILLIPS (2009)

These grades command different prices. For instance, Table 3 shows prices of two different grades of gum arabic from the 3 major producing countries. Note that the above grades are generally distinguished by the tree species: the first grades include

[1] These norms were adopted or modified by other regulations such as the EU Gum Arabic Specification (E414), the European Pharmacopeia, the United States Food Chemical Codex or the United States Pharmacopeia and the National Formulary (WILLIAMS and PHILLIPS, 2009).

the gum secreted by *Acacia senegal* and is referred to as 'hard gum' whereas the second grades include the gum secreted by *Acacia seyal* and is referred to as 'flaky gum'.

Table 3. Prices of gum arabic in major producing countries 2005-2006 (US$/ton)

Origin	Grade	Dec 2004	Sept 2005	May 2006	Incoterm
Sudan	Grade 1	1,650	4,300	4,800	FOB
	Grade 2	750	NA	NA	FOB
Chad	Grade 1	1,847	NA	NA	FOB/Douala
	Grade 2	1,020	NA	NA	FOB/Douala
Nigeria	Grade 1	1,150	3,000	4,200	CAF/Europe
	Grade 2	750	NA	1,500	CAF/Europe

NA: not available, Incoterm: International Commercial Terms
Source: ITC (2008)

Even though some of the exports figures are missing, it can be observed that the price of Grade 1 gum is always much higher than the price of Grade 2. Hence the absence of a grading system for a producing country is a serious problem as it implies the loss not only of the opportunity to transact with specific markets but also of price premiums that are associated with different grades.

Within the *Acacia senegal* species, the main factors affecting grades of gum arabic quality are different botanical sources (varieties), tapping methods, harvesting period and environmental factors (CHIKAMAI and ODERA, 2002): (1) the known varieties of *Acacia senegal* include var. *senegal,* var. *kerensis*, var. *rostrata* and var. *leiorhachis*. In the zones of study in Senegal and also in Sudan only the var. *senegal* occurs (COSSALTER, 1991); (2) tapping is the commonly used method of harvesting gum in Senegal and Sudan, it is carried out during the early part of the dry season during October/November (PHILLIPS, 2012). The modern tapping tool used in Sudan is a sharp spear (sonki), in Senegal, besides the sonki, an axe is also commonly used (OKATAHI and ONYIBE, 1999; IDRIS and HADDAD, 2012; CISSOKHO, pers. comm.). It is suggested that gum should be left to mature and form nodules at least for 14 days after which it can be harvested off the tree (DIONE and SALL, 1988). Depending on the area, this period can even be extended to 4 or 6 weeks (IDRIS and HADDAD, 2012). The long maturity period poses the risk of appropriation of gum by competing collectors particularly in communal forest where access to the common plots is unrestricted and the rules of management are unclear (SÈNE and NDIONE, 2007); (3) to maintain gum quality during gum collection, collectors need to apply appropriate tapping techniques, tap at the right time (following climatic and ecological indications), and respect the

waiting period after tapping. They should harvest gum off the tree carefully without taking it with the tree bark, and prevent it from falling on the soil. Post-harvesting handling is also important: indeed cleaning, proper drying and storage improve the quality of gum arabic (OKATAHI and ONYIBE, 1999; PHILLIPS, 2012). RAMLY (2012) emphasized the benefits of improving the technical know-how in the treatments and activities associated with gum production even if collectors generally learn the above good practices through contact with other collectors; (4) environmental factors are important in the production of gum arabic: BALLAL et al. (2005) and WEKESA et al. (2010) found that rocky soils, high soil temperatures and high rainfall lead to better yields. Problems with quality are that gum arabic is sometimes mixed with other types of gums to increase weight, harvested immaturely to get it off the tree before other collectors, uncleaned of its impurities, dried or stored improperly and not graded (SEIF EL DIN and ZARROUG, 1996; DEFCCS, 2005). Such problems make that quality of gum supplied is not reliable unless the collector or any subsequent buyer takes a deliberate effort to clean and grade it. Variations in quality have also led to design of artificial gum substitutes that have enhanced and reliable properties (AOKI et al., 2007). Therefore, gum producing countries, including Senegal, need to be aware of maintaining and improving the quality of the produced gum in order to retain and expand their market share.

4 Methodology

Two methodological approaches are followed: first, a visual inspection of gum quality was done on the field by collectors and primary traders and chemical analyses of gum arabic quality were done in the laboratory, the results obtained from these assessments were then compared; secondly, determinants of quality supply were examined in the context of current production and marketing practices.

4.1 Quality Measurements

A field assessment was done during the visit of 11 villages from the sylvopastoral zone and eastern region of Senegal between March and April 2010; 6 of these villages had been chosen for the purpose of training (described below) and the other 5 villages were randomly selected for a visit. In total, 27 samples of gum were obtained; these samples were randomly picked from sacks of the gum arabic intended for sale. They were assessed by collectors and traders in the village. Similar field assessments were successfully used in various contexts for instance to examine or validate the management practices (RORNIG et al., 1995; VIGIAK et al., 2005) or the soil suitability of crops (COOLS et al., 2003). A field assessment is criticised of being subjective (ABBOTT, 1999), yet according to STOCKING and MURNAGHAN (2001), it has the advantage of

providing a more practical view of the types of acceptable interventions. In the field assessment pertaining to the current study, samples were classified as of best, first, second or standard quality on the basis of intrinsic visible quality attributes including the size of the gum nodule and cleanliness.

An analysis of chemical components which determine gum properties and thereby its usage in different industries was done in the laboratory. Chemical analyses were done to determine intrinsic invisible quality attributes of all the 27 gum samples which were assessed on the field. These samples were ground into powder on a cutting mill (Retsch SM100) with a sieve of aperture size of 1mm. They were then solubilized in distilled water at a rate of 10 percent w/w (weight by weight). The solution was then filtrated on a filter with porosity P2 in order to eliminate the particles in suspension (sand, bark etc.). The laboratory analyses include measurements such as dry matter (determined on gum powder by heating at 103°C during 24h), mineral matter or ashes (determined on gum powder by combustion at 550°C during 4h), and the specific rotatory power (determined by direct reading of rotator power on a Bellingham + Stanley's ADP220 polarimeter). The compendium of food additive specifications by JEFCA (2006) details the general methods for analysing properties of substances.

Results from chemical analyses were compared with the field assessment to determine the extent to which the samples fulfilled the users' requirements. In order to have the margins of acceptability of gum arabic based on chemical measurements, two representative specifications of users provided the basis for comparison namely the JEFCA for food products in general on the international level and Valdafrique[2] for pharmaceutical products on the national level.

4.2 Analysis of Quality Supply by Gum Collectors

In the second step, the determinants of supply of quality are analysed for two visible attributes namely the size and cleanliness of the nodules: the bigger and/or the cleaner the gum nodule, the higher is its quality. The variable indicating the size of gum nodules is defined by the proportion in the quantity brought by the collector to the market: a large proportion of nodules that are smaller than 2 cm i.e., many nodules are less than 2 cm (coded as 0), a small proportion of nodules that are smaller than 2 cm i.e., a few nodules are smaller than 2 cm (coded as 1), a small proportion of nodules that are larger than 2 cm i.e., a few nodules are larger than 2 cm (coded as 2), and a large proportion of nodules that are larger than 2 cm i.e. many nodules are larger than 2cm (coded as 3). The variable indicating the cleanliness of nodules is defined by the

[2] Valdafrique operates in Senegal since 1943. It specializes in the processing of gum into final products such as medical tablets. It also transforms gum into a spry-dried gum powder which is used as a semi-raw product the gum-using industries.

proportion in the quantity brought by the collector to market: a small proportion of nodules that are clean (coded as 0), about half of the nodules that are clean (coded as 1), and a large proportion of nodules that are clean (coded as 2). These values indicate attributes of the ordered observed outcome in the supply of quality.

Following DIONE and SALL (1988), CHIKAMAI and ODERA (2002), and IDRIS and HADDAD (2012), determinants of quality include tapping aspects, post-harvest handling and environmental factors. These determinants are operationalised by the duration between tapping *Acacia senegal* tree and collecting the gum off the tree, type of forest management, participation in training on quality and time spent in post-harvest activities. We add control variables for environmental factors proxied by seasonal differences (which for instance imply differences in humidity, temperatures) and regional differences (which for instance express differences in soil characteristics and rainfall). Furthermore, we add market factors because they also influence the supply of gum quality. Here we include the place where gum is sold, trader experience, and price in previous season. Table 4 is an overview on the determinants of quality supply by collectors and their hypothesised influence.

Table 4. Description of the determinants of quality supply and expected influence

Variable	Description	Expected influence
Duration between tap and collection	Dummy variable: 1 if 14 days or more are taken between tree tapping and collection or 0 otherwise.	+
Forest management	Dummy variable: 1 if collection is organized in communal plots or 0 otherwise.	-
Post-harvest time	Approximate time (in minutes) the collector devotes to post-harvest activities (cleaning or sorting) divided by the total amount of gum he sold	+
Training	Dummy variable: 1 if the collector participated in training or 0 otherwise.	+
Sale place choice	Dummy variable: 1 if gum was sold to village boutique or 0 otherwise	+
Trader experience	Years of involvement in gum business	+
Price in previous season	CFA/kg	+
Seasonal differences	Dummy variable: 0 if collection was done in the beginning of season, 1 if collection was in the mid-season or 2 if collection was at the end of season.	-/+
Regional differences	1 for eastern Senegal or 0 for the Sylvopastoral zone.	-/+

Source: own survey

Two sessions of training on gum quality aspects were conducted each in the sylvo-pastoral zone (SPZ) and eastern region (ES) at the beginning of the gum season of 2009-2010 previous to beginning collection. The training was conducted in 3 villages in the sylvopastoral zone and 3 villages in eastern Senegal prior to the collection season of 2010, these villages were randomly selected across the sub-zones of gum arabic production in Senegal. In each region, 3 villages served a control group, with the aim of investigating whether farmers in the trained villages were going to supply gum of higher quality than farmers in the non-trained villages. Participants to the training were randomly selected in villages. Following these training sessions, monitoring of collectors was done between January and May 2010 with the purpose of recording the quality brought to the markets together with the specific details that explain the supply of quality. This monitoring was done for the 12 villages targeted in the study and it was conducted in markets where farmers respectively sell their produce. This implies 16 markets in both zones. Samples of collectors for monitoring were randomly constituted each monitoring day in a quota of 10 collectors per market. This implies that a certain trained collector in village X had the same probability of being interviewed in the process of monitoring as any other collector who had not participated in the training. The markets were visited three times in the season (beginning, mid and end of the collection season) resulting in 219 formal records (i.e., a 60 percent response rate).

Table 5 provides an overview of the descriptive statistics of the variables used as determinants of quality supply in terms of size of gum nodules and cleanliness.

In comparing determinants of the nodules size and cleanliness in pooled data or across the region, we observe significant differences in forest management, participation in training, choice of sale outlet, trader's experience, expected price, and harvest and sale of gum arabic either at beginning or during the middle of the season. The analysis of determinants of quality aspects is done through an ordered logit model because the observed attributes of the size or cleanliness of gum nodules which are the dependent variables indicate ordered categories of quality from low to high quality. According to Greene (2008), the ordered logit model is built around a latent regression $y^* = \boldsymbol{x}\boldsymbol{\beta}' + \varepsilon$ where y^* is unobserved; $\mathbf{x}$ is the vector of independent variables, and $\boldsymbol{\beta}$ is the vector of regression coefficients which are estimated.

Table 5. Descriptive statistics of determinants of quality supply

Variable	Undistinguished quality			Size of gum nodules				Cleanliness			Equality test	
	Senegal (219)	**SPZ (155)**	**ES (64)**	**Many < 2cm (89)**	**Few < 2cm (74)**	**Few > 2cm (46)**	**Many > 2cm (10)**	**Few clean (19)**	**Half clean (136)**	**Many clean (64)**	**Size X region**	**Clean-liness X region**
Distribution of quality attributes				0.41 (0.033)	0.34 (0.032)	0.21 (0.028)	0.04 (0.014)	0.09 (0.019)	0.62 (0.033)	0.29 (0.031)		
Duration between tap and collection (1: ≥14 days)	0.33 (0.470)	0.33 (0.471)	0.32 (0.469)	0.32 (0.471)	0.30 (0.460)	0.39 (0.493)	0.22 (0.441)	0.23 (0.427)	0.33 (0.485)	0.37 (0.484)	0.79	1.37
Forest management (1: commune)	0.52 (0.501)	0.39 (0.490)	0.84 (0.368)	0.44 (0.527)	0.37 (0.488)	0.67 (0.471)	0.48 (0.502)	0.61 (0.502)	0.41 (0.494)	0.73 (0.445)	7.45***	9.92***
Post-harvest time (minute/quantity)	5.83 (6.092)	4.93 (3.908)	8.01 (9.178)	4.65 (4.640)	7.14 (7.773)	5.76 (5.612)	6.82 (3.432)	5.82 (4.720)	4.68 (4.190)	8.27 (8.690)	2.31*	8.04***
Training (1: participated)	0.72 (0.452)	0.64 (0.480)	0.89 (0.317)	0.44 (0.527)	0.75 (0.434)	0.63 (0.488)	0.76 (0.432)	0.61 (0.502)	0.71 (0.454)	0.75 (0.175)	3.46***	6.22***
Sale place choice (1: village boutique)	0.56 (0.497)	0.63 (0.484)	0.38 (0.489)	0.45 (0.500)	0.58 (0.497)	0.76 (0.431)	0.44 (0.527)	1	0.54 (0.500)	0.48 (0.504)	5.89***	6.45***
Trader experience (year)	15.6 (9.387)	19.0 (7.596)	7.3 (8.169)	17.7 (9.099)	12.3 (10.303)	17.2 (7.757)	13.2 (1.716)	17.2 (6.907)	18.1 (8.730)	9.9 (8.975)	18.03***	21.74***
Price in previous season (CFA/kg)	616.0 (158.82)	529.3 (77.66)	825.8 (96.77)	584.8 (133.87)	711.5 (171.33)	543.6 (116.38)	516.7 (86.60)	560.5 (149.61)	564.3 (124.56)	742.2 (157.41)	17.84***	38.33***
Begin-season (1: if collection at the beginning)	0.30 (0.458)	0.32 (0.469)	0.24 (0.429)	0.61 (0.491)	0.15 (0.358)	0	0	0.06 (0.236)	0.37 (0.484)	0.22 (0.417)	20.99***	5.75***
Mid-season (1: if collection in mid-season)	0.32 (0.469)	0.37 (0.484)	0.22 (0.419)	0.19 (0.395)	0.38 (0.488)	0.43 (0.501)	0.67 (0.500)	0.5 (0.514)	0.3 (0.480)	0.22 (0.417)	4.70***	5.14***
End of season (1: if collection at end)	0.38 (0.485)	0.31 (0.464)	0.54 (0.502)	0.20 (0.404)	0.47 (0.503)	0.56 (0.501)	0.33 (0.500)	0.44 (0.511)	0.28 (0.450)	0.56 (0.500)	7.64***	18.69***
Region (1: Eastern Senegal)				0.13 (0.036)	0.62 (0.057)	0.11 (0.046)	0	0.17 (0.090)	0.10 (0.025)	0.73 (0.055)		

[a] Equality test refers to ANOVA test for continuous variables and Pearson chi-square test for categorical variables.
*** significant at 1% level, ** significant at 5% level; * significant at 10% level, + significant at 15% level

Source: own survey

5 Results and Discussion

5.1 Assessment of Quality

The classification of samples according to the field criteria and results from chemical analyses are presented in Table 6.

Table 6. Field assessment of quality and results of chemical analyses for 27 gum arabic samples

Village	Reference	Field assessment			Laboratory assessment		
		Sample rank	Description		DM (%)	MM[a] (%)	SRP[a] (rotation angle)
			Size of nodules	Cleanliness			
L1	CEH1	1st best	large pieces	Clean	88.76	4.30	-28.11
L1	CEH2	1st	small pieces	Clean	89.33	3.49	-22.03
L1	CEH3	1st	small pieces	Clean	88.92	9.71	-30.26
L1	CEH4	2nd	small pieces	Dirty	89.89	7.55	-29.17
G1	CEH5	1st	large pieces	Clean	89.10	3.65	-31.48
G1	CEH6	2nd	large pieces	Dirty	89.94	16.58	-32.33
G1	CEH7	standard	large pieces	A bit clean	89.49	4.74	-29.41
Y	CEH8	1st	large pieces	A bit clean	88.97	3.99	-32.35
Y	CEH9	2nd	large pieces	Dirty	90.00	6.78	-30.50
V	CEH10	1st best	large pieces	Clean	89.26	3.66	-29.79
V	CEH11	1st	large pieces	Dirty	88.55	3.44	-32.27
V	CEH12	2nd	small pieces	Very dirty	88.59	3.81	-29.54
T	CEH13	1st	large pieces	Clean	88.63	3.39	-25.04
T	CEH14	2nd	large pieces with debris	Clean	88.90	3.89	-29.21
T	CEH15	standard	large pieces with debris	Clean	88.73	4.14	-31.70
L2	CEH16	1st	large	Dirty	89.30	3.37	-29.62
L2	CEH17	2nd	large	Dirty	89.42	9.69	-18.96
L2	CEH18	3rd	large	Dirty	88.48	14.47	-28.85
S1	CEH19	standard	small pieces	Clean	88.08	3.01	-30.36
D	CEH20	standard	small pieces	Clean	88.33	2.72	-34.11
G2	CEH21	standard	very small pieces	Clean	88.53	3.19	-31.86
S2	CEH22	1st	small pieces	Clean	88.11	8.07	-29.84
S2	CEH23	2nd	small pieces	Clean	88.44	8.22	-27.48
S2	CEH24	3rd	small pieces with debris	Quite clean	88.40	3.70	-32.19
K	CEH25	1st	very small pieces	Dirty	88.69	4.82	-36.96
K	CEH26	2nd	very small pieces with debris	Very dirty	88.90	4.77	-32.66
K	CEH27	3rd	very small pieces with debris	Most dirty	88.63	5.50	-37.30

DM: dry matter, MM: mineral matter, SRP: specific rotatory power
[a] results on DM basis

Source: field responses, DEH and CIRAD

There are some clear findings derived from the above analysis: (1) the description of quality on the field is subjective, it differs from village to village, the gum considered as good quality by one village need not be so in another village; (2) laboratory measures show small variations in the dry matter content, this is found to be between 88.08 and 90.00 percent; variations in mineral matter and rotatory power are large: the ash content varies between 2.72 and 16.58 percent and rotation is between -37.30 and -18.96 degrees; (3) generally, good quality (best, first or standard quality) is associated with clean gum and low mineral matter, indicating less contamination.

The above results were compared on the basis of two quality criteria of gum arabic. These are (1) Ash content (mineral matter) should not exceed 4 percent; and (2) Optical rotation should be between -26 and -34 degrees (JEFCA, 2006, and VALDAFRIQUE, 2011) (Table 7).

Table 7. Assessment of quality requirements for samples of gum arabic

Village	Total number of samples	Laboratory assessment		Field assessment 1st or standard	Field vs. lab
		Ash content	Optical rotation		
L1	4	1	3	3	0
G1	3	1	3	2	1
Y	2	1	2	1	1
V	3	3	3	2	2
T	3	1	2	2	0
L2	3	1	2	1	1
S1	1	1	1	1	1
D	1	1	1	1	1
G2	1	1	1	1	1
S2	3	1	3	1	0
K	3	0	1	1	0
Total	27	13	22	16	8

Source: own survey

Out of the 27 tested samples, only 13 samples fulfilled the ash content criterion whereas 22 samples fulfilled the optical rotation criterion. The field assessment was based on visible attributes namely the size of nodules, and cleanliness. Among the 27 samples, 16 samples were considered of first (best) or good standard quality. When comparing the laboratory assessment to the field assessment, only 8 samples among these 16 were correctly found to fulfil the optical rotation and ash content criteria jointly. Among the samples of low quality as assessed on the field, only 2 were incorrectly classified by collectors as they were found to be of good quality in accordance with the laboratory analyses.

By comparing the field and laboratory assessment of gum quality to the user specifications in the international food and local pharmaceutical industries, we found that low quality is in most cases confirmed to be bad by any assessment, the visual attribute for low quality is the lack of cleanliness irrespective of any size of the nodule and high quality from the perspective of collectors and traders on the field is not always good in terms of laboratory assessment; in this case, only 50 percent of high quality samples were correctly classified on the field. Furthermore, more samples were considered of bad quality by the laboratory tests than after visual inspection. This divergence in quality measurements influences the rejection rates at higher levels in the supply chain. At this point it important to note that even though many of the samples are labelled as 'bad', this does not mean that they are utterly useless. Rather, they may be used in other industries for instance in painting or textile where specific quality requirements are not very stringent (DERRICK et al., 1999). Therefore, it is necessary to find such industrial niches. Of course, due to the small number of tested samples, the above results cannot be generalized, yet they lead to the interesting observation that if supply of high quality on the field was to increase, there would be a higher likelihood to fulfill quality requirements in terms of laboratory assessment. This observation leads us to investigating the determinants of quality supply.

5.2 Determinants of Quality Supply by Gum Collectors

Table 8 shows the distribution of gum supplied by collectors with regard to the size and cleanliness of gum nodules.

Table 8. Two-way table: gum cleanliness X Size of gum nodule

Gum cleanliness	Size of gum nodule				Total
	Many < 2cm	Few < 2cm	Few > 2cm	Many > 2cm	
Few clean	0	7	11	1	19
Half clean	72	29	28	7	136
Many clean	17	38	7	2	64
Total	89	74	46	10	219

Pearson $\chi^2(6) = 52.18$***

Source: own calculations

A cross tabulation of cleanliness and size of gum nodules shows that these attributes of quality are significantly different. For instance, more than 70 percent of gum supplied contains nodules which are small, at the most less than 2cm in diameter. These small nodules are however mostly clean. The gum which is not clean consists of less than 10 percent of all the gum supplied, but this unclean gum is of big nodules, at least larger

than 2cm in diameter. Such differences justify the treatment of these attributes as separate dependent variables in subsequent analyses. Table 9 shows the ordered logit results for quality supply.

Table 9. Ordered logistic results (nodule size: 4 categories in SPZ, 3 categories in ES; nodule cleanliness 3 categories in SPZ and ES)

Variable	Size of gum nodules			Cleanliness of gum nodules		
	Senegal (219)	SPZ (155)	ES (64)	Senegal (219)	SPZ (155)	ES (64)
Duration between tap and harvest (1: ≥14 days)	0.444+ (0.353)	0.603+ (0.486)	1.140+ (0.911)	0.492+ (0.391)	0.392 (0.524)	0.310 (0.801)
Forest management (1: commune)	-0.388+ (0.328)	-0.359 (0.393)	-1.986* (1.117)	-0.094 (0.358)	-0.520+ (0.455)	-0.843+ (0.799)
Post-harvest time (ln minute/quantity)	0.251* (0.142)	0.157 (0.275)	0.099 (0.308)	0.306* (0.178)	0.016 (0.324)	0.224 (0.296)
Training (1: participated)	0.777** (0.404)	0.321+ (0.522)	1.554+ (1.098)	0.063 (0.439)	0.522+ (0.580)	0.615 (0.956)
Sale place choice (1: village boutique)	1.502*** (0.366)	1.311*** (0.498)	2.177** (0.988)	-0.570+ (0.410)	-0.930* (0.581)	-1.822* (1.064)
Trader experience (year)	-0.036* (0.023)	-0.046+ (0.031)	-0.172*** (0.066)	0.036+ (0.027)	0.022 (0.0388)	0.036 (0.067)
Price in previous season (CFA/kg)	-0.002* (0.001)	-0.004* (0.002)	-0.010** (0.005)	-0.001* (0.002)	-0.006** (0.003)	-0.009* (0.005)
Mid-season (1: if collection in mid-season)	3.172*** (0.438)	7.280** (3.099)	1.564+ (0.993)	-0.453+ (0.389)	-0.999* (0.561)	4.643 (1.682)
End of season (1: if collection at end)	2.391*** (0.444)	7.168** (3.133)	-0.140 (0.913)	0.241 (0.445)	2.325*** (0.757)	-2.011* (1.164)
Region (1: Eastern Senegal)	-1.072 (0.649)			2.692*** (0.755)		
Cut-off1	0.736 (1.192)	5.590 (3.353)	-13.259 (5.649)	-0.976 (1.317)	0.718 (1.671)	-11.052 (5.341)
Cut-off2	2.819 (1.204)	6.859 (3.360)	-7.715 (5.333)	3.141 (1.343)	6.197 (1.778)	-9.050 (5.253)
Cut-off3	5.122 (1.228)	9.217 (3.367)				
Log-likelihood	-208.136	-129.457	-36.616	-148.707	-83.809	-36.043
LR-chi square	106.70***	104.94***	25.73***	82.53***	34.48***	20.56**
Pseudo R-square	0.204	0.288	0.260	0.217	0.171	0.222
% good predictions	53.88	62.58	76.56	78.08	69.73	65.63

*** significant at 1% level, ** significant at 5% level; * significant at 10% level, + significant at 15% level

Source: own calculations

The results of the models of quality supply with respect to the size of gum nodules and cleanliness of gum nodules for the pooled data of Senegal and separately for the gum production regions show that some variables consistently had a positive effect as expected (duration between tap and harvest, post-harvest time and participation in training), other variables consistently had a negative effect (forest management and price in previous season) and the remaining variables had contradictory effects. The effect of forest management was expected but that of the price was unexpected. Coefficients are repeatedly significant for some variables but only the choice of the boutique as the sale place and price in previous seasons are consistently significant across all models. All the models have a high correct prediction of over 50 percent.

All in all we found on the one hand that the large gum nodules are supplied by collectors who respect the sufficient duration required for gum maturity between tree tapping and gum harvesting (at least 14 days), spend long time on post-harvest activities, participate in training, and choose to sell to the village boutique. In comparison with the beginning of the season, larger gum nodules are obtained during the mid-season or towards the end of season of collecting and selling the gum. Collection in communal forests has a negative effect on the size of nodule; such competition increases due to a high price in previous season, hence the latter also has a negative effect on quality. Moreover, traders who are newer in gum business prefer large nodules. On the other hand, the clean gum nodules are supplied by collectors who respect a sufficient duration required for gum maturity between tapping and harvesting of gum, and spend long time on post-harvest activities. Experienced traders prefer cleaner nodules whereas selling to the village boutique and the high price in the previous season have a negative effect on cleanliness. Furthermore, in comparison to the beginning of the season, the gum collected during the mid-season is less clean. Eastern Senegal is the region where cleaner gum is mostly produced.

Harvest and post-harvest handling were found to have a positive influence on supply of quality: the long duration between tapping and harvesting gum and the more time spent on post-harvest practices (including cleaning and sorting) lead to better gum. This implies that there is need for an emphasis on the basics of the techniques of gum harvesting and of practices to maintain and improve its quality. Collectors can acquire the related knowledge and skills through experience, but trainings are needed specially in terms of linking the collector's knowledge to the quality aspects that are important to the users; the training conducted at the beginning of the season proved to be important in that respect.

The behaviour of a village boutique owner is not consistent with respect to quality attributes: he is interested in the big nodules whose inspection involves a low cost and is associated with large quantity. However, he ends up with the less clean gum: for

him, an emphasis on cleanliness not only reduces the quantity to trade but also leads to a problem of enforcing the quality requirements as it would be difficult and costly to reject gum: repeated rejections of the supplied gum lead to a negative social outcome and collectors will not go to him in the future which means that he can lose a market altogether. Hence, the less experienced trader who would like to establish himself in business and needs to build a large supply base, does not strongly enforce quality requirements. These results are reversed in regard to the trader' s experience in gum business, allowing us to safely assume that village boutique owners are younger traders who are interested in larger nodules than the older traders. Proper assessment of cleanliness is achieved from experience; hence the experienced traders are indeed more interested in clean gum.

The effect of price is discussed in a forest management context. It is normally expected that a higher price generates incentive to upgrade quality; however, this is only possible if competition in common forests is controlled. In case of unregulated competition, high prices in previous seasons make collectors to expect high prices on the market and they want to increase the supply of quantity in order to increase their revenues. This focus on quantity becomes detrimental to quality: gum is not left to mature enough but is just picked when the nodule is still small and has not sufficiently dried. Such gum is easily found with impurities (SEIF EL DIN and ZARROUG, 1996; DEFCCS, 2005). Cases of declining quality due to rising prices have been observed in other non-timber products as well (e.g., LAMIEN et al., 1996; NEUMANN and HIRSCH, 2000): increased competition leads to increased levels of extraction of the resource before maturity thereby leading to low quality because there is a strong incentive to harvest the products before a competitor does. The nature of resource tenure is indicated to be the main raison behind competition: in private and community-managed forests where competition is regulated, quality is better, in open-access forests where the 'first come, first serve' rule operates, insecure tenure over collection areas leads to risk of over-exploitation and inability to manage quality (BELCHER and SCHRECKENBERG, 2007).

Another effect of price on quality can be associated with differences in relative supply for quality: at high price levels, there is relatively more supply of lower quality whereas at low price levels, there is relatively more supply of higher quality. This relationship between price and quality is analysed through a simulation process where the price in previous season henceforth referred to as 'price') is varied, keeping constant other variables, and effects on probabilities associated with quality attributes are observed. These simulations were based on the estimation results of the ordered logit model. Figure 1 shows simulation results of pooled data at the average values in Senegal and for specific values of certain explanatory variables separately for the sylvopastoral zone and eastern Senegal for a gum price ranging from 350 to 900 FCFA.

Figure 1a. Quality supply response to changes in price at average values (pooled data)

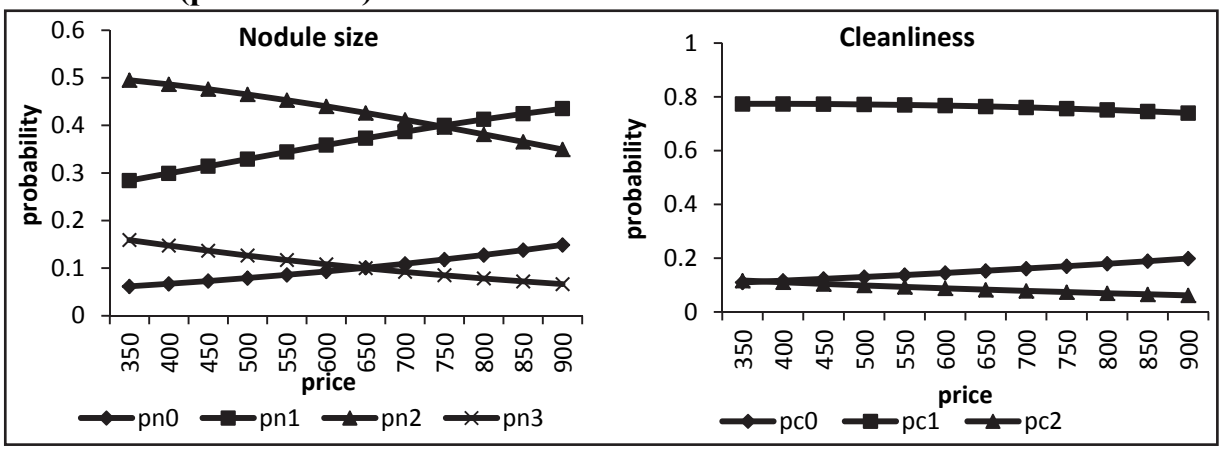


Figure 1b. Quality supply response to changes in price in SPZ if management=0, training=1, sale choice=1

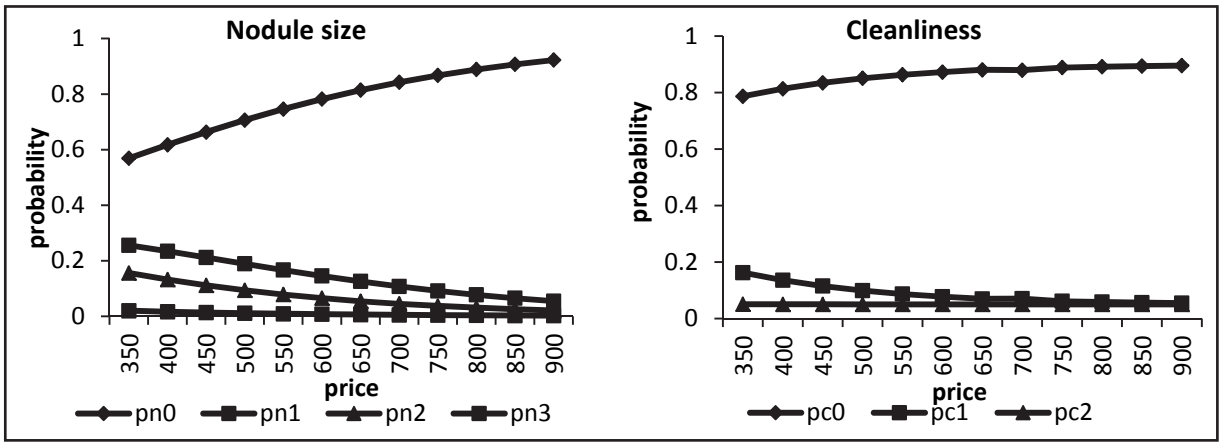
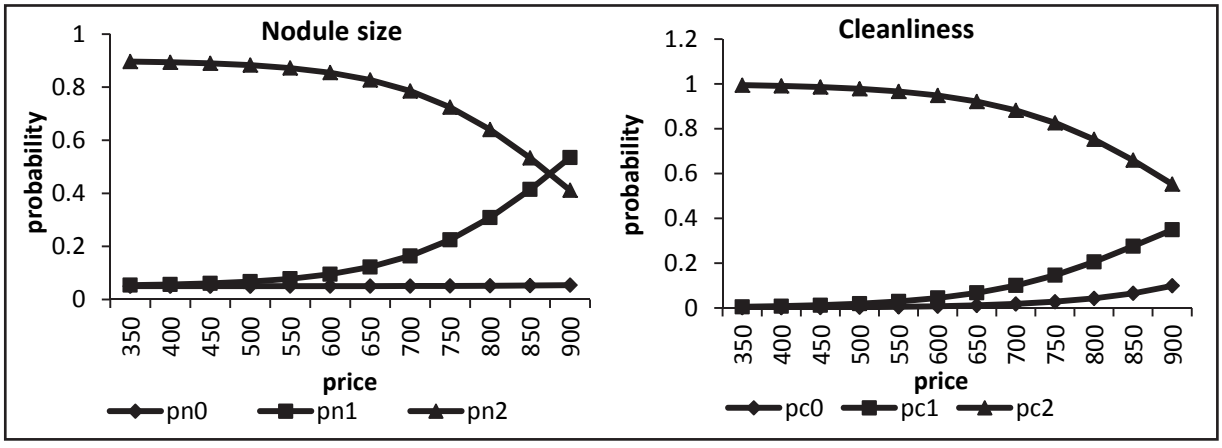


Figure 1c. Quality supply response to changes in price in ES if management=1, training=1, sale choice=1



Source: own calculations

In Figure 1a, price is allowed to vary whereas the remaining explanatory variables are maintained at their average values using the pooled data. Simulations show that the probabilities of supplying low quality (pn0 or pn1 associated with nodules of small size and pc0 associated with less clean nodules) directly increase with price whereas the probabilities of supplying high quality (pn2 or pn3 associated with nodules of large size and pc1 or pc2 associated with cleaner nodules) decline with an increase in price. In Figures 1b and 1c, simulations are extended to the case of organising collection in private property in the sylvopastoral zone or collecting gum in communal forests in eastern Senegal respectively. In both zones collectors are assumed to be trained, and sales are made to the village shop. Price is allowed to vary and the remaining explanatory variables are maintained at their average values. Apart from small variations, the same results hold: in the Sylvopastoral Zone, due to an increase in price, for the size of gum nodules, pn0 increases while pn1, pn2 and pn3 decrease; for cleanliness pc0 increases while pc1 and pc2 decrease. In eastern Senegal, due to an increase in price, for the size of gum nodules, pn0 and pn1 increase while pn2 decreases; for cleanliness pc0 and pc1 increase while pc2 decreases. The simulation results can be associated with the effort of the collector towards achieving a certain quality level, his expected income and competition in communal forests. They can also be explained by the trader's behaviour: at a high price, the collectors whose supply of low quality is not rejected by a trader will continue supplying low quality whereas at the low price, the collectors whose supply of low quality may be rejected by a trader will have to put more effort to increase quality at least to a top segment of the gum quality, in order to reach a target income.

With regard to environmental factors, differences within the season and across regions confirm findings of CHIKAMAI and ODERA (2002) that indeed there are conditions associated with humidity, wind, heat, rainfall or soil which affect gum quality. Taking the beginning of season as the base, we found that the size of nodules supplied increases throughout the season except for eastern Senegal where towards the end of the season, gum nodules are smaller than nodules harvested at the beginning of season and cleanliness declines in mid-season to increase again at the end of season except again for eastern Senegal where towards the end of the season, gum nodules are less clean than gum harvested at the beginning of season. Furthermore, on a regional level, the sylvopastoral zone is endowed with bigger nodules than eastern Senegal whereas eastern Senegal has cleaner gum than the Sylvopastoral Zone. Note that eastern Senegal has 2 cut-offs for the size of nodules.

6 Conclusion

The attempt of translating the users' quality criteria into the production and marketing practices of producers by linking the laboratory measurements of quality to the field assessment and then investigating determinants of quality has led to several interesting findings. First, it has become evident that it is indeed useful for the scholars of quality to bring together the production and consumption sides because their perceptions and requirements may not always converge. In this study of the quality of gum arabic, it was found that the objective but not directly visible measures of quality are not always directly linked to visible quality attributes in the field: while the on-field visible attributes of gum arabic postulate that the particular gum is of good quality, its invisible quality attributes are not always fulfilled. Knowledge of gum quality supplied helps in the process of targeting market niches or reducing risk of rejection by the buyer.

Secondly, the good quality gum on the field increases the likelihood of obtaining the good quality on the basis of invisible attributes. Hence, collectors should be sensitized to put effort in the respect of the good harvest and post-harvest practices so that they supply good quality gum. Trainings for gum collectors should be regularly conducted as knowledge and awareness creation are probably the main building blocks for quality-oriented production.

Thirdly, the current study has strengthened the need to understand the role of forest management on the quality of the gum. Clear rules of management are needed to counteract the influence of market forces (price) on competition in forests.

Fourthly, including specific market factors in the study of quality revealed that traders' behaviour is rather uncertain towards quality. As actors in the supply chain and intermediaries between the collectors and users, they should have a definition of quality that is coherent and responsive to the actions and needs of collectors and users respectively, hence it is important that traders are also targeted in training. A common understanding will reduce the quality uncertainties which also negatively affect the price that traders pay and they can play an important role in the search and transmission of information on quality. Moreover, high prices can increase the probability of supplying low quality if the price is increased uniformly without any quality differentiation. Hence, the supply of good quality should be accompanied by its own reward in terms of a premium. Such premium enables a distinction between the high and low quality gum.

There are other several aspects of focus by further research including the expansion of the laboratory research base (in terms of the number of samples and types of measurements) so that the findings could be generalised and an investigation of the

influence of specific environmental factors on quality. Proxies for such environmental factors were included in the study but it is necessary to include real measures so that collectors can distinguish clear influences and anticipate quality changes between and during seasons. Such studies would be beneficial in terms of determining the consistency of quality. Furthermore, there is need to understand the determinants of demand and supply of differentiated quality and as the next step of linking quality practices to users' specifications, it is important to make an investigation of requirements for implementing certification for gum arabic or other non-timber forest products.

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