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Research Article

Quality function deployment (QFD) reveals appropriate quality of charcoal used in barbecues

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ABSTRACT: Charcoal is an important product widely used in food preparation in many parts of the world, both in developing and developed countries. However, most of the time, the main qualitative characteristics for consumers and the environment are not considered during production. Developing energy-efficient products for food preparation has been a constant pursuit of the charcoal supply chain and the aim of this study was to interact with charcoal consumers to become conversant with and classify the characteristics suitable for barbecue use. To achieve our objectives, we used the quality function deployment (QFD) method. The qualitative needs were deployed together with a multidisciplinary team assembled through interviews with several charcoal consumers. The cause and effect factors were also determined by the Ishikawa method. The technical demands of the product had the following priority order: ease of ignition, rapid formation of embers and flames, fast preparation of grilled food, and affordability. The factors relating to raw material, labor, and methodology emerged as decisive in the quality of charcoal for barbecue, and future studies should consider incorporating the results obtained in the production of charcoal and the respective consumer analysis.

Keywords: charcoal grill, quality management, product development, sustainable, clean energy production

Introduction

Harnessing fire as a tool has certainly boosted the evolution of man in many ways, just as the use of charcoal has also become a part of human daily life for various applications. There are references which indicate that the first practice of food preparation (cooking) by humans was with biomass and charcoal (Neuhaus, 2003; Khalessi et al., 2008; Cramer et al., 2011; Warnes, 2008). Nowadays, the use of charcoal is commonplace across several social classes, and in a number of them, food preparation involves techniques considered gourmet, such as the dirty steak, which entails direct contact of food with charcoal. In other cases, this same technique simply reflects a popular demand in cooking, and is currently attracting attention from governmental organizations representing many interested parties across the social classes (Vicente et al., 2018; Wang et al., 2019).

The number of people in the world who use biomass for food preparation is estimated at 3 billion, a major part of which is the use of charcoal in developing countries (Bentson, et al., 2013; IEA, 2004; Lask et al., 2015). A number of reasons for a preference for charcoal is related to its economical acquisition cost, low emission of particulates during combustion, and modest maintenance of equipment requirements associated with its production (Bentson et al., 2013; Tippayawong et al., 2019; Vicente et al., 2018). Despite these considerations, there are few measures in place to control the quality of the energy characteristics of the product, investigated and developed in the production process for consumer availability. Even in large countries producing industrial charcoal, such as Brazil, measures that can be taken to control the quality of charcoal for domestic use on a barbecue are not known (Dias Júnior et al., 2015a). In the year 2017, Brazil produced approximately 6 million tons of charcoal, of which 12 % was destined for domestic use (EPE, 2018; IBÁ, 2017).

Quality management systems should adopt the meeting of consumer expectations as a fundamental principle as this would allow for greater involvement of public opinion and, consequently, the development of innovations and improvements in the production process (Bolar et al., 2017; Chan and Wu, 2002; Milan et al., 2003; Tutu and Anfu, 2019). With consumers involved in the charcoal production process reporting their qualitative needs, the products would have more efficient technical specifications for barbecuing and would not cause harmful effects to the environment. The QFD method assists in translating consumer needs into technical specifications of products and processes, and ensure that they can be followed by operating systems (Akao, 1996; Aguiar et al., 2017; Eldermann et al., 2017; Jafarzadeh et al., 2018; Schillo et al., 2017). Considering the importance of meeting customer needs, as well as maximizing the value bestowed on the product by the consumer, the aim of this study was to interact with charcoal consumers in order to discover and classify the appropriate characteristics of charcoal for barbecue use.

Materials and Methods

The starting point of the QFD project was the definition of team members, formed by people who are part of the Special Charcoal Commission (CECV/SP) of the Secretariat of Agriculture and Supply (CODEAGRO/SP) of the state of São Paulo, Brazil (SAA/SP) (Latitude 23°32′50.44′′ S; Longitude 46°38′11.16′′ W; 763 m a.s.l.). The Commission was composed of producers, distributors, traders, technical experts, and others interested in matters relating to the charcoal supply chain. The questionnaires created adopted a technical-qualitative approach, using simple expressions aimed at the furthering of analysis of the consumer's perspective of the charcoal grill business (Cheng and Melo Filho, 2007; Govers, 1996). The issues included information on the characteristics of the desired charcoal, raw material, packaging, and problems already experienced by consumers during its use in barbecue.

Thus, the guiding questions for the selection of products that would be analyzed were identified as follows: which product or product characteristic define us? Who will be our customers? What competing products will be used as a reference? How does the QFD approach fit with charcoal? To investigate consumer needs, the following questions were posed: What do you expect from a charcoal barbecue? What are the main desirable characteristics of charcoal for barbecuing? What are the main problems you have had with charcoal when preparing a barbecue? How often do you prepare charcoal grilled foods? What features in the charcoal and in your packaging would you like made available by the producers? What is your favorite charcoal brand and why? What is the most important aspect when buying charcoal and what is the least remembered aspect?

The questionnaires were developed making sure questions were posed in a logical order, whose script contained mixed, open (free responses), and multiple-choice questions. The issues included information on the characteristics of the particular charcoal desired, raw material, packaging, and problems already observed by consumers during their use in barbecuing.

Quality function deployment (QFD)

The QFD methodology was developed according to the proposals of Cheng and Melo Filho (2007) and the suggestions of Dias Júnior et al. (2015b). These suggestions have been applied to the forestry sector and are consistent with the objectives of this research. The required quality, product description of charcoal in consumer language, product quality characteristics (technical descriptions), and the "roof" (correlation matrix) were developed for the construction of a quality matrix or house, see Figure 1.

The steps involved in QFD were: I) determination of the quality required ("What") by consumers; II) verification of the degree of importance of each "What"; III) quality assessment required by customers (planned quality); IV) deployment of the qualities required ("What") in terms of technical requirements ("How"); V) determination of the relationship between "What" and "How"; and VI) determination of the quality projected by the technical team and assembly of the correlation or roof of the house quality.

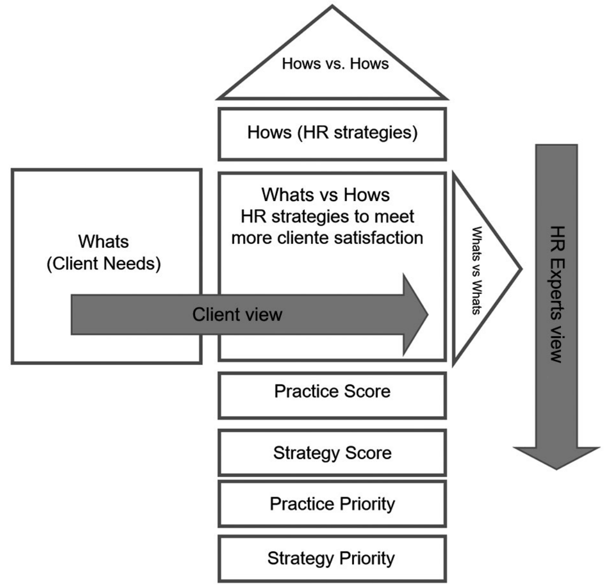


Figure 1 – House quality. Source: Jandaghi et al. (2010).

The determination of the quality demanded by consumers was conducted through interviews and the application of questionnaires specific to this research, which were directed to the customers of commercial establishments that resell the product, owners and patrons of bars, steakhouses, and diverse consumers, all located in the city of Piracicaba, in the state of São Paulo, Brazil (Latitude 22°43′31″ S; Longitude 47°38′57′′ W; 528 m a.s.l.). This study presented questionnaires to 1,025 people consulted. Selection of the respondents sampled followed the recommendations of Levine et al. (2000), as per Equation 1:

$$n = \frac{N * \hat{p} * \hat{q} * (Z_{\alpha/2})^2}{\hat{p} * \hat{q} * (Z_{\alpha/2})^2 + (N-1) * E^2} \quad (1)$$

where: n = number of individuals in the sample; N, the total number of population; $\hat{p}$, the population proportion of individuals belonging to the category that we are interested in studying; $\hat{q}$ the proportion in the population of individuals not belonging to the category of study interest ($q = 1 - p$); $\hat{p} * \hat{q}$ = if the values of p and q are unknown, replace p and q by 0.5; $Z_{\alpha/2}$, the critical value corresponding to the desired degree of confidence; E, the error margin or maximum error of estimation (5 %) which identifies the maximum difference between the sample proportion and the true proportion of the population (p).

After assessing the questionnaires, key consumer needs were identified and discussed with the support team members. Later, in a brainstorming session, the main qualities required for formation of the matrix or quality house were determined. The distinction between implicit and explicit requirements was differentiated so that the Kano model could be considered (meeting requirements and customer satisfaction), as presented in Figure 2.

The Kano model suggests that quality implies a relationship between objective and subjective attributes (Kano, 1991). Thus, quality requirements that were similar or related were organized by affinity (Cheng and Melo Filho, 2007). In order to evaluate the items required, a degree of importance (DI) was assigned by the consumer to each quality item as follows: (1) of no importance, (3) important, and (5) very important. The identification of the projected quality in terms of consumer opinion enabled improvements for each characteristic and/or aspect required. The analysis of competition was carried out by evaluating "our product" (A) in relation to competitors (B and C). Values (1, 3, and 5) were assigned for each item, based on the same criterion used for the quality required.

The improvement plan was an elaboration of the team's judgment (CECV/SP) of each quality required, analyzing the degree of importance and the comparative evaluation between competing products. Thus, an improvement index (IM) was constructed by dividing the improvement plan of the assessment made by the number of consumers. The values attributed to the sales argument (AV) were 1.0 for each item that was not highlighted in the market and 1.2 for those with items and/or attractive aspects (Cheng and Melo Filho, 2007).

The absolute weight (AW) of the quality required was obtained according to the degree of importance (DI), the improvement index (IM), plus the sales argument (SA) of each quality item required (Equation 2). The relative weight (RW) was calculated as a function of the absolute weight of the quality required and the sum of the absolute weights (Equation 3):

$$AW = DI \times I \times SA \quad (2)$$

$$RW(\%) = \left(\frac{AW}{\sum AW}\right) \times 100 \quad (3)$$

where: AW = absolute weight of required quality; DI, the degree of importance; IM, the improvement index; SA, the sales argument, and RW, the relative weight.

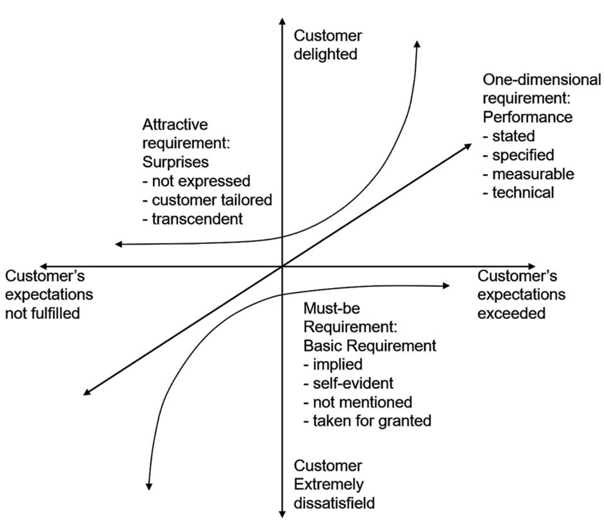


Figure 2 – Kano model relates product requirements to consumer satisfaction. Source: Berger et al. (1993).

For the development of the technical quality requirements, the product characteristics and measurable qualities were identified through brainstorming, in order to evaluate the fulfillment of consumer requirements. From the basic objective the aspects related to it, the measurable measures, were defined. These aspects were, simply, measurable or controlable measures. The general aspects were derived from the answers to the questions: "What to do?" (answer = objective); "How to do it" (the answer will be how to respond to the goal). The questions were asked until the means were exhausted.

After the definition of all the primary aspects, the evaluation phase was implemented by judging the adequacy to the objective and its viability; next it was classified as "viable" or "not feasible"; the infeasible scenarios were eliminated. To identify the level of interrelationship between the quality characteristics and the qualities required, the team adopted characteristics with strong, moderate, and weak correlation, having weights of 9, 3, and 1, respectively. The final grade was given after the team consensus, individually filling in the correlations.

The projected quality (technical product requirements) integrated the absolute weights (AW) and relative weights (RW), classification of technical requirements, evaluation of specifications, and technical objectives related to the quality of the charcoal for barbecuing. The technical specifications were obtained together by the team, establishing the characteristics of each requirement and comparing them with those of the competition. Subsequently, the specifications were organized by affinities and, then validated by evaluating the questions regarding performance according to the following criteria: (↑) = the higher the better; (↓), the lower the better; (↑↓), has a specific range; and, (○), the change in value is not relevant (adapted from Govers, 1996).

The correlation matrix (roof of the house of quality) was elaborated by the correlations derived from the technical requirements, intending to define the priorities of each item in the future. These correlations had attributed weights of: (++) = positive strong; (+), positive weak; (–), weak negative; and, (– –), strong negative. "Our product" (A) was determined by the charcoal trademark product most often reported by consumers during the interviews. Products B and C (competitors) were chosen based on the sampling of five categories of commercial stores in the city of Piracicaba, SP, Brazil as follows: supermarket chainstore, independent supermarkets, butcher shops, gas stations, a group of "others" formed mostly by bakeries, fruit stands, and minimarkets.

After sampling and analysis of the observed frequency of each product, the following criterion was used: product "B" was the most frequent of all the products collected (can be more easily found by the consumer), and product "C" was the designation of an imaginary charcoal product that met the characteristics referenced by Resolution n. 40 SAA, Seal Charcoal Premium (SAA, 2015) and European Standards EN 1860-2 (2005), appliances, solid fuels and firelighters for barbecuing, Part 2: barbecue charcoal and barbecue charcoal briquettes – requirements and test methods. The two standards regulate the minimum characteristics necessary for the use of charcoal in barbecues in the state of São Paulo (Brazil) and Europe, respectively. The technical quality requirements and their parameters, according to these two standards, are presented in Table 1.

For comparison and analysis between "our product" and competing products, the materials were analyzed in the laboratory according to their physical, chemical, and mechanical properties by means of standardized tests, as per Table 2.

Causes and effects associated with the quality of charcoal for barbecue

The tool of the cause and effect diagram or Ishikawa ("fishbone") was used to survey the main factors that contribute to the quality of charcoal, spanning from its production to its availability to the consumer. These factors were identified from brainstorming discussions by the team after the analysis of applied questionnaires, report studies, books, and scientific articles on the quality of barbecue charcoal (Dias Júnior et al., 2015a, b; Warnes, 2008). The aim was to identify the factors associated with the main needs of the consumers as regards barbecue charcoal. This type of diagram provides an overview of the different variables capable of influencing an attribute, which is useful in identifying problems or opportunities to improve the system (Lestander et al., 2012; Montgomery, 2009).

Data analysis

The data were evaluated through descriptive statistics, observing the percentages for the main quality factors, as well as the interpretation house quality built therein and relationships obtained.

Results and Discussion

The research study had a total of 1,023 consumers of charcoal, which was considered satisfactory for the population analyzed according to the criterion of representation and sampling (Levine et al., 2000). The matrix or quality house presented in Figure 3 represents the systematization of the production planning of charcoal for barbecue use based on the QFD methodology.

By developing the required quality (Step 1 of the matrix, Figure 3), the team defined the technical quality requirements that can meet the demands of consumers of charcoal barbecue, based on 26 items established as

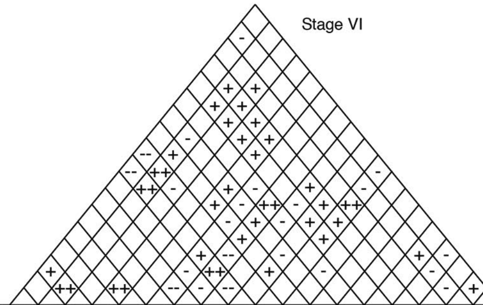
Table 1 – Quality requirements according to standardized quality standards in Brazil and Europe.

Parameter	Resolution n°. 40 SAA, Seal Charcoal Premium (Brazil)	EN 1860 European Standards (Europe)
Aspect	Bright black color, cannot present pieces of semi- carbonized wood and wood residues or ash, and preferably dust-free.	Solid carbonization product of wood or other plant material that has not been chemically treated.
Bulk density	> 200 kg m^{-3}	> 130 kg m^{-3}
Particle Size (< 12 mm)	≤ 5 % of the net weight of the packaging must be < 12 mm	From 0 mm to 150 mm, where <10 % may exceed 80 mm in size; at least 80 % should be > 20 mm and 7 % < 10 mm.
Moisture	< 5 %	≤ 8 %
Fixed carbon content	> 73 %	≥ 75 %
Ash content	< 2 %	≤ 8 %
Packing	Container and handle set, made of recyclable material recommended to be paper, and present technical product information.	The packaging shall communicate to consumers information about the type of product (charcoal or charcoal briquettes), mass, safety and handling aspects, production lot number.
Raw material (wood)	It recommends the use of wood from planted forest, proven by the legality of origin by the competent official body.	Do not report.

Table 2 – Tests carried out for the analysis of charcoal for barbecue.

Variables	Unity	Reference
Moisture	%	ASTM (1977)
High heating value	MJ kg^{-1}	NBR 8633 (ABNT, 1984)
Apparent density	g cm^{-3}	NBR 9165 (ABNT, 1985a)
Bulk density	kg m^{-3}	NBR 6922 (ABNT, 1981)
Fixed carbon content	%	ASTM (1977)
Volatile materials content	%	
Ash content	%	
Combustion index	dimensionless	Quirino e Brito (1991); Dias Júnior et al. (2015b)
Friability	%	NBR 8740 (ABNT, 1985b)

Defining improvement	
○	Unimportant change in value
↑	Higher value is better
↓	Lower value is better
Correlation roof	
(++)	Positive strong
(+)	Positive weak
(-)	Negative weak
(--)	Negative strong
Correlation between requirements	
⓪ = 9	Strong
◯ = 3	Moderate
Δ = 1	Low



Primary level	Secondary level	Consumer importance degree	Moisture content	Apparent density	Bulk density	True density	Porosity	Volatile materials content	Fixed carbon content	Ash content	Calorific value	Friability	Combustion index	Rate of heat degradation	Reactivity	Charcoal from eucalyptus wood	Charcoal from other wood species	Dimensions of charcoal	Type of packaging	Packing mass	Our product (A)	Competitor B	Competitor C	Quality plan	Improvement index
Quality required (Stage I)	Defining improvement →		↓	↓↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↓	○	○	○	↓↑	↓↑	↓↑	Stage III: Market Bench-marking				
Be easy to ignite	Ease of ignition	5	⓪												⓪						3	5	5	5	1.67
	Rapid formation of embers and flames	5	Δ	⓪		Δ	Δ					Δ			⓪						3	5	5	5	1.67
	Low moisture content	5	⓪		⓪						⓪	⓪									5	3	5	5	1.00
	Auxiliary fuel for ignition	1	Δ																⓪		5	3	1	5	1.00
Easy to put out the fire	Low reactivity	1		Δ				Δ	⓪		Δ				⓪	Δ	Δ				1	1	1	1	1.00
Good combustion performance	Feed yield per mass of charcoal	5		⓪	⓪		Δ	Δ	⓪				⓪	⓪		Δ				Δ	5	5	5	5	1.00
	Low need to feed equipment with charcoal	3	Δ					⓪	⓪		⓪		⓪	⓪	⓪			Δ		Δ	5	3	5	5	1.00
	Fast preparation of grilled food	5	Δ	Δ	Δ		Δ				⓪		⓪		Δ						3	3	5	5	1.67
	High charcoal temperature	5	⓪			Δ		⓪	⓪	Δ	⓪		⓪	Δ							5	3	5	5	1.00
Few charcoal fines	High mechanical resistance	3	⓪	⓪		Δ			Δ				Δ			Δ	Δ	Δ			5	3	5	5	1.00
	Less easily broken	3	⓪	⓪	Δ				Δ			⓪			Δ	Δ					5	3	5	5	1.00
	Pieces of charcoal larger than 100 mm	5																⓪	Δ		5	5	5	5	1.00
	Resistant protective packaging	3																	⓪		5	5	5	5	1.00
Absence of flames in the combustion	Flames smaller than 30 mm	3		Δ	Δ	Δ	Δ	⓪	⓪						⓪	Δ	Δ	Δ			3	3	5	5	1.67
No smoke in combustion	Low emission of particulate and volatile materials	3					Δ	⓪	⓪	Δ	Δ		Δ	Δ		Δ	Δ	Δ			3	3	5	5	1.67
	Heat load permeability	3		Δ	⓪							Δ			Δ	Δ	Δ	⓪			5	5	3	5	1.00
	Low generation of charcoal fines	5	Δ	⓪								⓪			Δ			⓪		Δ	5	3	3	5	1.00
Provide food flavor	Absence of semi-carbonized wood	1		Δ	Δ			Δ	Δ	Δ	Δ	Δ						Δ			5	3	5	5	1.00
Good price for purchase	Affordable consumer price	5														⓪	⓪		⓪	⓪	3	3	3	5	1.67
Ease of transport	Packing with handle	3																	⓪		5	3	5	5	1.00
	Packing with dimensions suitable for transport	3																Δ	⓪		5	5	3	5	1.00
	Product mass for easy transportation	1		Δ	Δ											Δ	Δ	Δ	⓪	⓪	3	5	3	5	1.67
Differential packing	Protection for charcoal	1																	⓪		5	5	5	5	1.00
	Resistant to tear and moisture	1																Δ	⓪		3	3	5	5	1.67
	Easy to open	3																	⓪		1	1	5	3	3.00
	With food recipes	3																	⓪		1	1	5	3	3.00
	Degree of importance (Weight absolute)		53	57	41	7	11	48	66	6	42	30	44	32	58	26	24	44	94	30					
	Degree of importance (Weight relative)		7.4	8.0	5.8	1.0	1.5	6.7	93	0.8	5.9	4.2	6.2	4.5	8.1	3.6	3.4	6.2	13	4.2	Stage V				
	Unity		(%)	g/cm³	kg/m³	g/cm³	(%)	(%)	(%)	(%)	MJ/kg	(%)	A	g/min	A	E	O	cm	P/PL	kg					
	Our product (A)		4.7	0.4	225	1.24	70	19.6	78	2.1	36	14	0.6	2.7	O	E	N	10	P	2.5					
	Competitor B		5.0	0.4	213	1.7	78	27.3	71	1.7	37	8.7	0.62	2.72	O	E	N	>10	P	3					
	Competitor C		>5	>0.28	>280	>1.0	>70	>25	>75	>1.5	>33.5	>10	>0.8	↓	↓	↑	↓	<10>	NI	NI					
	Technical Product Benchmarking (Stage IV)																								

Quality characteristics (Stage II)

Figure 3 – Quality house for the aspects of barbecue charcoal.

measurable factors. Thus, the relationships between required quality and technical requirements indicate the degree of dependence between them (Step 3, Figure 3). It is possible to identify strong correlations between several items, such as ease of ignition and moisture content, rapid formation of embers and flames and fixed carbon content, ease of breaking and friability, size of charcoal pieces (in excess of 100 mm), and type of packaging.

The indicators for the projected quality (Product Benchmarking, Step 4, Figure 3) were classified according to the relative weight of each quality characteristic, evidencing those that deserve attention. In order of increase, the list is as follows: ash content, true density, porosity, charcoal other than eucalyptus wood, eucalyptus wood charcoal, friability and mass of product, degradation rate, bulk density, calorific value, combustion and dimensions of charcoal, volatile material content, moisture content, bulk density, reactivity, fixed carbon content, and type of packaging. It is recommended that the charcoal for barbecue use has a low ash content (< 5 %), as it is a mineral agent that decreases the calorific value and increases the amount of residues at the end of the barbecue. Ashes can also cause incrustations in barbecue equipment (Dias Júnior, 2015b). The true density indicates the degree of efficiency of the carbonization process and, together with the apparent density, influences the porosity of the charcoal. Thus, they influence the thermal conductivity, the heat supply time, and the energy flow between the pieces of charcoal in the barbecue equipment, allowing for good combustion performance and yield of the food preparation process. The use of wood from eucalyptus plantations results in homogeneous charcoal with more regular characteristics for the barbecue. These discussions may have an impact on the increase in the mechanical strength of the charcoal and on the reduction in friability, since it is possible to plan a suitable carbonization process for a type of wood that does not present high variability in its properties. In addition, the packaging is made so as to protect the charcoal from moisture and mechanical impacts resulting from handling which may contribute to the undesirable generation of charcoal fines (< 5 cm).

The immediate chemical composition is one of the most analyzed parameters for quality analysis of charcoal for barbecue use. High fixed carbon content is suggested by the fact that it reduces the generation of flames and greater heat supply, while the content of volatile materials does not contribute to these aspects. These properties make it possible to increase the reactivity of charcoal, which is the capacity to regenerate with oxygen gas (Ma et al., 2017). More reactive charcoal results in the greater ability to react with atmospheric air and generate heat at high temperatures for the barbecue (Ma et al., 2017; Dufourny et al., 2019).

This classification shows that the type of wood and the carbonization process to decrease the values of the ash content, friability, and raise both the values of the variable calorific value and combustion index of the charcoal must be verified (Assis et al., 2016). These aspects were mentioned by the team based on the economic feasibility of modifying the quality of the product without significantly burdening the production process. The study reveals that the majority of the charcoal distributed for barbecue use does not originate from systems and production methodologies adequate for the cooking of food. The products are the result of the carbonization process that were initially proposed to obtain charcoal for the steel industry. Wood as a raw material is also poorly suited to producing charcoal for barbecue because consumers have indicated the need for high density charcoal; and the greater the density of wood the greater the density of charcoal (Assis et al., 2016; Dias Júnior, 2015b; Wang et al., 2017).

The house roof or correlation matrix (Step 5, Figure 3) presented relationships between several quality indicators. Among them, it is possible to emphasize the strong positive correlations between apparent density and bulk density and between fixed carbon content and calorific value. As for weak negative relationships, we can mention those observed between ash content and calorific value and those between the moisture and friability of charcoal (Assis et al., 2016; Dias Júnior et al., 2015b; Dias Júnior et al., 2016; Rueda et al., 2015; Silva et al., 2018). These results deserve to be highlighted by any possible modifications and/or adaptations that may be necessary in the production process, aiming at the reduction of failures and low quality of the final product.

The items suggested in the quality requirement determination step (Table 3), based on the degree of importance and identified 26 items ("What"), were classified into ten groups. It was observed that consumers suggested aspects related to the handling, use, charcoal properties, and product packaging characteristics. The degree of importance showed that the charcoal should be easy to ignite rapidly from embers and flames, have low moisture content, fast preparation of grilled food, high charcoal temperature, have pieces of charcoal in excess of 100 mm in the packaging, and present less charcoal fines. These items were graded as five (very important). In general, charcoal for food preparation (barbecue) must meet the minimum requirements of Brazil and Europe as presented in Table 2. Additionally, an important fact to remember is that the polycyclic aromatic hydrocarbons (PAHs) are not included in the standards. Dias Júnior et al. (2017) identified 16 potentially toxic compounds present in barbecue charcoal. The authors highlight the relevance of quality control measures so that this does not become an aggravating public health problem, especially in developing countries that use biomass as the main energy source for cooking food. Figure 4 presents the absolute weights and relative weights, ordered for all technical constraints, with reference to the planned quality.

Table 2 presents the main needs as follows: ease of ignition, rapid formation of embers and flames, fast preparation of grilled food, and affordable consumer price (8 %). Then, at 7 %, the needs related to the packaging of products are shown, including how easy products were to open and food recipes (as seen on food packaging). It is important to mention that the needs with the lowest relative weight (1 %), among all those surveyed, were those related to the presence of auxiliary fuel for ignition charcoal, low combustibility efficiency of charcoal,

Table 3 – Conversion of consumer needs into required qualities.

Primary level	Secondary level	DI	Our Product (A)	Competitor B	Competitor C	Plan	IM	SA	AW (%)	RW (%)
Be easy to ignite (1)	Ease of ignition (1.1)	5	3	5	5	5	1.67	1.20	10.00	7.87
	Rapid formation of embers and flames (1.2)	5	3	5	5	5	1.67	1.20	10.00	7.87
	Low moisture content (1.3)	5	5	3	5	5	1.00	1.00	5.00	3.93
	Auxiliary fuel for ignition (1.4)	1	5	3	1	5	1.00	1.00	1.00	0.79
Easy to put out the fire (2)	Low reactivity (2.1)	1	1	1	1	1	1.00	1.00	1.00	0.79
Good combustion performance (3)	Feed yield per mass of charcoal (3.1)	5	5	5	5	5	1.00	1.20	6.00	4.72
	Low need to feed equipment with charcoal (3.2)	3	5	3	5	5	1.00	1.20	3.60	2.83
	Fast preparation of grilled food (3.3)	5	3	3	5	5	1.67	1.20	10.00	7.87
	High charcoal temperature (3.4)	5	5	3	5	5	1.00	1.20	6.00	4.72
Few charcoal fines (4)	High mechanical resistance (4.1)	3	5	3	5	5	1.00	1.00	3.00	2.36
	Ease of breaking (4.2)	3	5	3	5	5	1.00	1.00	3.00	2.36
	Pieces of charcoal larger than 100 mm (4.3)	5	5	5	5	5	1.00	1.20	6.00	4.72
	Resistant protective packaging (4.4)	3	5	5	5	5	1.00	1.20	3.60	2.83
Absence of flames in the combustion (5)	Flames smaller than 30 mm (5.1)	3	3	3	5	5	1.67	1.00	5.00	3.93
No smoke in combustion (6)	Low emission of particulate and volatile materials (6.1)	3	3	3	5	5	1.67	1.00	5.00	3.93
	Heat load permeability (6.2)	3	5	5	3	5	1.00	1.00	3.00	2.36
	Low generation of charcoal fines (6.3)	5	5	3	3	5	1.00	1.20	6.00	4.72
Provides food flavor (7)	Absence of semi-carbonized wood (7.1)	1	5	3	5	5	1.00	1.00	1.00	0.79
Good price for purchase (8)	Affordable consumer price (8.1)	5	3	3	3	5	1.67	1.20	10.00	7.87
Ease of transporting (9)	Packing with handle (9.1)	3	5	3	5	5	1.00	1.20	3.60	2.83
	Packing with dimensions suitable for transport (9.2)	3	5	5	3	5	1.00	1.00	3.00	2.36
	Product mass for easy transportation (9.3)	1	3	5	3	5	1.67	1.00	1.67	1.31
Differential packing (10)	Protection for charcoal (10.1)	1	5	5	5	5	1.00	1.00	1.00	0.79
	Resistant to tear and moisture (10.2)	1	3	3	5	5	1.67	1.00	1.67	1.31
	Easy to open (10.3)	3	1	1	5	3	3.00	1.00	9.00	7.08
	With food recipes (10.4)	3	1	1	5	3	3.00	1.00	9.00	7.08

Where: DI = degree of importance (5: very important, 3: important and 1: no importance); IM = improvement index; SA = sales argument; AW = absolute weight; RW = relative weighting.

absence of semi-carbonized wood, and packaging that protects the product against environmental conditions.

The results of the comparative analysis (Figure 5) between the products show that, in general, "our product" (A = more informed by consumers) was higher than product B, the most commercially available product. However, there was a technical comparison resulting in a draw with Competitor C, a fictitious product with quality characteristics referring to the state of São Paulo (Brazil) and Europe. Thus, if the intention was to expand the sales market, "our product" (A) would need to be adjusted to achieve better parameters.

The charcoal production process is related to several factors determined by the cause and effect diagram (6 Ms). The factors that determine the quality of the charcoal for barbecuing were analyzed, and the ones that interfered most in the process are raw material (wood), labor (work force), and methodology (carbonization) (Figure 6).

The wood is the defining element of charcoal quality (Assis et al., 2016; Dufourny et al., 2019). Although the genetic material *Eucalyptus* spp is the most recommended species, its physico-chemical properties dictate its transformation into charcoal (Demirbas, 2004; Protásio et al., 2017). In addition, wood moisture and size (diameter and length) are related to its accommodation in the masonry carbonization system and process carbonization temperatures. In relation to the material, the packages protect the charcoal (final product) against moisture and during handling and transportation, avoiding breakage and generation of charcoal fines.

The production methodology is another limiting factor. Carbonization parameters (time, temperature control, ignition), the decision of when to end the process, sifting, packaging, and transport all contribute decisively to the quality of the product (Dias Júnior et al., 2015b; Meira et al., 2005; Sangsuk et al., 2018). The charcoal, being a hygroscopic and friable material, can suffer effects at any of these production stages (Dias Júnior et al., 2016). Whenever problems or opportunities are identified, actions should be planned and executed so that the system can be reassessed by verifying the impact of the changes made, in order to make improvements. This cycle model is referred to in PDCA cycle quality management (Plan, Do, Check and Action) or Deming cycle.

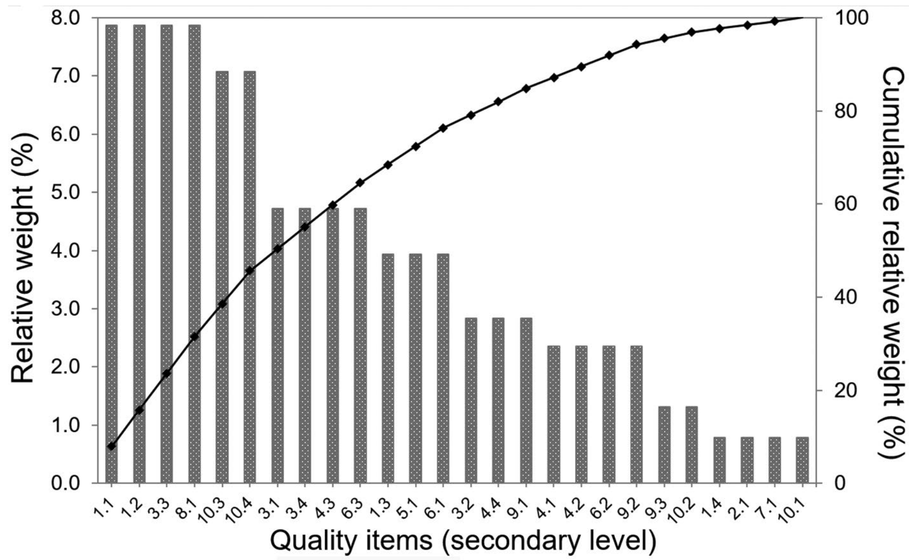


Figure 4 – Planned quality constraints with their respective absolute and relative weights. Where: 1.1 = Ease of ignition; 1.2 = Rapid formation of embers and flames; 1.3 = Low moisture content; 1.4 = Auxiliary fuel for ignition; 2.1 = Auxiliary fuel for ignition; 3.1 = Feed yield per mass of charcoal; 3.2 = Low need to feed equipment with charcoal; 3.3 = Fast preparation of grilled food; 3.4 = High charcoal temperature; 4.1 = High mechanical resistance; 4.2 = Less easily broken; 4.3 = Pieces of charcoal larger than 100 mm; 4.4 = Resistant protective packaging; 5.1 = Flames smaller than 30 mm; 6.1 = Low emission of particulate and volatile materials; 6.2 = Heat load permeability; 6.3 = Low generation of charcoal fines; 7.1 = Absence of semi-carbonized wood; 8.1 = Affordable consumer price; 9.1 = Packing with handle; 9.2 = Packing with dimensions suitable for transport; 9.3 = Product mass for easy transportation; 10.1 = Protection for charcoal; 10.2 = Resistant to tear and moisture; 10.3 = Easy to open; 10.4 = With food recipes.

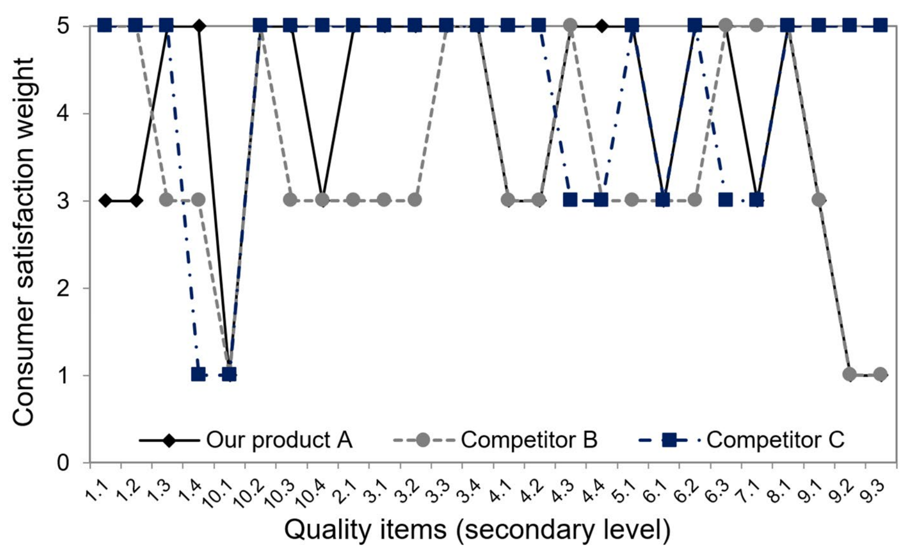


Figure 5 – Benchmarking of quality requirements where: 1.1 = Ease of ignition; 1.2 = Rapid formation of embers and flames; 1.3 = Low moisture content; 1.4 = Auxiliary fuel for ignition; 2.1 = Auxiliary fuel for ignition; 3.1 = Feed yield per mass of charcoal; 3.2 = Low need to feed equipment with charcoal; 3.3 = Fast preparation of grilled food; 3.4 = High charcoal temperature; 4.1 = High mechanical resistance; 4.2 = Less easily broken; 4.3 = Pieces of charcoal larger than 100 mm; 4.4 = Resistant protective packaging; 5.1 = Flames smaller than 30 mm; 6.1 = Low emission of particulate and volatile materials; 6.2 = Heat load permeability; 6.3 = Low generation of charcoal fines; 7.1 = Absence of semi-carbonized wood; 8.1 = Affordable consumer price; 9.1 = Careful packing; 9.2 = Packing with dimensions suitable for transport; 9.3 = Product mass for easy transportation; 10.1 = Protection for charcoal; 10.2 = Resistance to tearing and moisture; 10.3 = Easy to open; 10.4 = With food recipes.

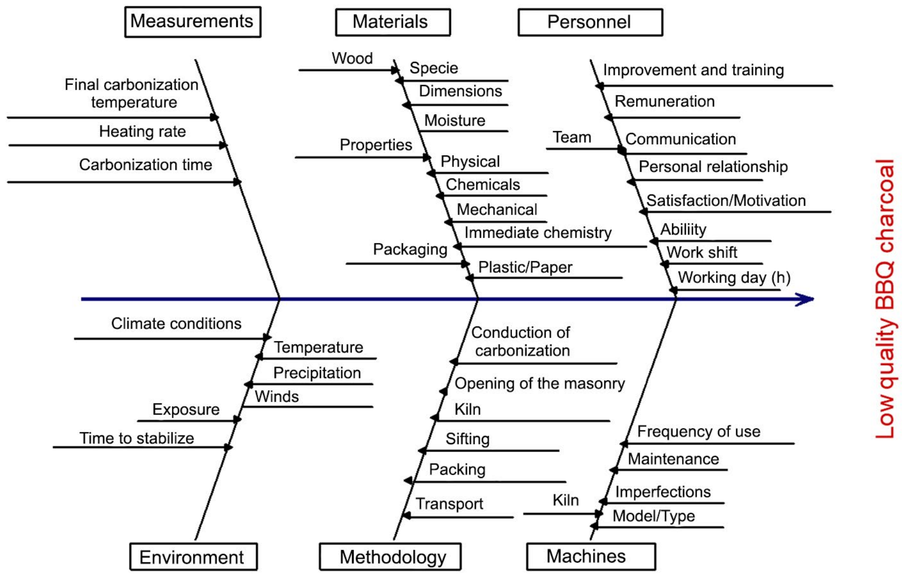


Figure 6 – Contributing factors to problems in the quality of charcoal for barbecue.

In Brazil, the charcoal that meets the domestic demands usually has its origin of production in the region where the product is marketed, being mostly small and medium producers that use handmade masonry systems of (Meira et al., 2005). Given this, practically the whole process is marked by the decision-making of the carbonizing staff. Thus, their qualification, skill, training, remuneration, satisfaction, and motivation with the work can contribute to the final quality of the charcoal. Faced with these and other factors pointed out by the diagram, action should be taken in order to make a decision to improve the production process and, consequently, the quality of charcoal available to consumers.

Among the possible actions to be taken, we recommend that the charcoal supply chain aimed at the domestic barbecue segment should be specifically designed to meet consumer satisfaction. For this, the carbonization systems (masonry or metallic) should allow for good conversion yields of the wood to charcoal, combustion of the non-condensable gases, and condensation of the pyrolignous liquid. These measures address the concepts of environmental sustainability, occupational health, and the dynamics of the supply chain by obtaining multiple products (charcoal and pyroligneous liquid). In addition, charcoal must have the characteristics required by customers. High density, fixed carbon content, and calorific value are the most important. The charcoal comes into contact with the person who prepares the barbecue and with the food through the gases and particulates emitted by the combustion. Quality charcoal barbecue use ensures that the product is clean and not harmful.

Low ash content is important to prevent fouling of the grilling equipment. The packaging needs to include several items of product information about the origin, production and quality. This will promote consumer safety when acquiring charcoal. It would be interesting to innovate in the production of charcoal packaging as well so as to provide the consumer with items to facilitate transportation, ignition, food recipes, and grilling techniques (such as dirty steak, for example), which are all measures to be tested.

Conclusions

We reveal the main qualities demanded by the consumers of charcoal for barbecuing in descending order as follows: ease of ignition, rapid formation of embers and flames, quick preparation of grills, and affordable price to the consumer.

The factors related to the raw material (wood), labor, and methodology (carbonization) were pointed out by the cause and effect diagram as being the most decisive in effect on the quality of barbecue charcoal.

We suggest future studies consider the incorporation of the results obtained in the production of charcoal and the respective analysis of consumers. We also suggest that actions be taken that are aimed at enhancing the charcoal supply chain for barbecuing to provide quality products to the consumer and address social and environmental issues.

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Authors' Contributions

Conceptualization: Dias Júnior, A.F.; Brito, J.O. Data acquisition: Dias Júnior, A.F.; Andrade, C.R.; Andrade, A.M. Data analysis: Dias Júnior, A.F.; Milan, M.; Souza, N.D. Design of Methodology: Dias Júnior, A.F.; Milan, M.; Brito, J.O.; Andrade, A.M. Writing and editing: Dias Júnior, A.F.; Milan, M.; Brito, J.O.

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