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Impact of grazing management on forage qualitative characteristics: a review

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Abstract: The main system for feeding cattle in Brazil is the forage-based. It happens due to low cost and high potential of forage production, which can be widely explored in a tropical climate country. Although, the nutritive value of the forage oscillates according to the grazing management. The success in production is related to the three main stages: herbage growth, consumption by grazing animals and conversion into animal product, maximizing profitability while providing sustainability. Thus, the objective with this literature review is to address detailed information on how grazing management can affect qualitative indicators of forage plants.

Keyword: canopy vertical structure, forage accumulation, forage stratum, nutritive value.

Contextualization and analysis

In Brazil, forages is a basal resource used in a large scale for feed ruminant animals. This factor is associated with the low source cost, high amount of forage accumulation (Pedreira et al., 2014) and the nutritional value provided to the animals.

Thus, to maintain or improve productive indices in Brazilian livestock, some attention should be done not only to the animal component, but also to characteristics related to the grasslands, such as: perennially, rapid regrowth after defoliation, tolerance to animal presence, nutritive value adequate and quality (Pedreira et al., 2013).

According to Collins & Fritz (2003), the potential that a plant has to producing a desired animal response is called quality, and the nutritive value is the forage chemical composition and its digestibility (Mott, 1970). It is directly connected to the proportion of the plant cell wall and the degree of lignification.

The forage quality and the nutritional value are closely linked to the type of management and the needed of adapting using phenotypic plasticity (Gianoli, 2004). As a result, the scientific community tries to understand the interaction between forage production x grazing management x animal nutrition.

Thus, to intensify animal production in forage-based systems is required knowledge on forage morphological (Pedreira et al., 2009) and

physiological (Pedreira et al., 2015) attributes. It will provide understanding of the whole system and strengthen decision-making (Pedreira & Pedreira, 2014)

In this context, the purpose with this review was to clarify how grazing management influences the forage qualitative indicators.

Importance of grasslands for livestock in Brazil

Since the beginning of the colonization process, livestock production plays an important role in Brazil. However, even with considerable growth in the colonial period, only from the 1960's, the North and Midwest regions of the country started to expand livestock systems. Initially, in the Midwest region, the state that was the most prominent in this expansion was Goiás, and from that moment, it spread to other Brazilian states, concentrating mainly in the south of the Pantanal. From there, it was spread by the entire Midwest region (Teixeira & Hespagnol, 2014).

The expansion of cattle production system in the Cerrado and the Amazon region started from the 1970's onwards boosted the expansion of pastureland cultivated in Brazil (Faria et al., 1996). Currently, the area occupied by cultivated pastures, according to estimates by ABIEC (2017a), reach 169 million hectares, leaving the initial mark of 25 million hectares. Brazilian pastures are occupied by a herd

of 218 million cattle (IBGE, 2016), and it is estimated that only 12.5% of the Brazilian herd are produced in an intensive system (ABIEC, 2017b), in which pasture is not the only food source. Nowadays, livestock farming contributes with 29.8% of the Brazilian Gross Domestic Product, reaching U\$ 117 billion in 2017 (Cepea, 2018).

The economic highlight of this activity is mainly due to its pasture being the main food source of the cattle herd, which has one of the lowest costs of meat production in the world, estimated at 60% of the Australia costs and 50% of the United States (Ferraz & Felício, 2010). In addition, Brazil has extremely favorable conditions for the forage production, with climate, territorial extension, among others.

Although these numbers are indicative of the system evolution, the productivity indexes of the Brazilian livestock can still be substantially improved. The use of tools that support decision-making in the property, as forage allowance with better nutritional value, can increase system efficiency. Therefore, researches in forage-based livestock system can help to increase the efficiency, which may provide to the Brazilian producers more competitiveness in world livestock production.

Quality and nutritional value associated with forage plant

Quality is the potential that a forage has to produce animal response (Collins & Fritz, 2003). It can be associated to chemical composition, digestibility and voluntary consumption by the animals, among other forage factors (Mott, 1970). Generally, forage quality and nutritive value are considered synonymous, but nutritive value refers only to the forage chemical composition and its digestibility (Mott, 1970), which is directly related to the proportion of the plant cell wall and the tissues lignification. The amount of cellular content determines the proportion of nutrients completely available. When it comes to cell content, it comprises the amount of protein, carbohydrates, sugars, lipids, organic acids and ashes that are available and free from the lignin effect (Van Soest, 1982).

In practice, in grazing systems, the animal performance reflects the forage quality. In this case, where pasture is the main component of the diet, the forage quality is determinant of the animal product, such as meat, milk, wool, etc.

Numerous factors affect the forage quality as temperature, maturity stage, leaf-to-stem ratio, grass-legumes mixtures, fertilization, variety effects and harvesting effects.

Maturity is the factor most influenced by external factors, such as species and temperature, but it is also the one that most influences the variables that affect nutritional value.

With the advancement of maturity or growth stage, there is a decline on the forage nutritive value. This happens because after the first weeks of regrowth, where the protein and digestibility levels are higher, there is an increase in the proportion of structures that provide plant support. There is a need to increase stem tissues, which reduce the cellular content amount, formed by constituents with high digestion, and increase the fiber deposition at the cellular level, which results in slow and low forage digestion.

According to Collins & Fritz (2003), the variation in forage quality is influenced by many factors. These can be divided in primary and secondary factors. Among the primary factors, three stand out as follows: forage species, stage of maturity and harvest conditions. Among the secondary factors can be listed: temperature, soil moisture during growth, soil fertility and cultivar. However, the regrowth phase (maturity) and consequently the harvest conditions are the factors that most affect the nutritive value.

With the advancement in maturity the forage nutritional value usually decreases, causing changes in the chemical composition, such as increase in the lignification with the decrease in leaf:stem ratio; reduction in crude protein (CP) contents; increase in the dry matter, minerals, cellulose and lignin contents; which results in digestibility reduction (Costa et al., 1998b).

However, Van Soest (1982) proposed that there are exceptions, especially with forage of *C₃* physiological metabolism and temperate climate. It should be noted that in some species, leaf and stem may not present a marked decline in nutritional value and quality with maturity, such as alfalfa (*Medicago sativa* L.).

Indeed, as maturity progress, changes in the composition in the plant may occur (Costa et al., 2007), as well as, changes in fertilization, genetic differences, seasons of the year and crop successions (Gomide, 1976). This author proposed that as the plant growth and its age advances, usually occur reduction in the N, P and K elements contents, mainly attributed to a dilution effect of the mineral elements.

According to Ramos (1997), the productive and nutritional attributes undergo changes in situations of climatic conditions favorable to the forage accumulation, age and morphological development. In pastures that reached maturity or were incorrectly management, there is, usually, a decrease in the CP content and an increase in the fiber content (Pedreira et al., 2013). Thus, maturity at harvest is considered the first factor to affect the nutritional value. The digestibility of young plants may be equivalent to that of concentrated feed. During the first two to three weeks of growth, temperate species may have a digestibility greater

than 80%, decreasing over time as the stem begins to develop (Collins & Fritz, 2003).

This reduction in digestibility is caused by the increase in the proportion of support tissues that have higher cell wall content. These are formed mainly by xylem and sclerenchyma liable to lignification. Depending on the lignification degree, the tissues are indigestible in the bovine rumen (Paciullo, 2002). Thus, there is an inverse relationship between quality (nutritional value plus consumption) and maturity (Sulc et al., 1997), and in some cases productivity may be inversely related to forage quality (Buscaglia et al., 1994).

Nunes et al. (1984) and Gomide & Queiroz (1994) analyzed the CP levels in marandu palisade grass at the advanced stage of maturity, reporting values from 51 to 57 g.kg⁻¹. When assessing CP levels in *Brachiaria decumbens*, Ferrari Junior et al. (1994) showed that the values decreased from 82 to 54 g.kg⁻¹ of CP, at 42 and 84 days of growth, respectively. Ruggieri et al. (1995) reported protein levels of 183 g.kg⁻¹, for marandu palisade grass harvested at 14 days of regrowth, demonstrating the importance of defoliation management, in order to manipulate the forage chemical composition and nutritive value.

Jonker et al. (2016) observed decreased of 29 g.kg⁻¹ dry matter in CP values and 78 g.kg⁻¹ dry matter in organic matter digestibility when there was a change in the growth stage from vegetative to mature.

Modulation of the nutritive value of forage plants

To understand the of nutrient dynamic in plants is essential to management animal production. The maximum animal production (such as meat, milk and wool) occurs only if the nutrient requirements had provided for products synthesis. Generally, when animals receive only forage as food, the energy, protein, minerals and vitamins are available to production is lower than the animal's genetic potential (Minson, 1990).

There are some ways to modulate the forage nutritional value (Minson, 1990). Among the morphological aspects, the leaf:stem ratio influences the forage quality and nutritive value. It modifies the chemical composition and animal consumption with lower leaf:stem ratio (Forber & Coleman, 1993). A high leaf:stem ratio represents high forage protein, digestibility and consumption (Wilson, 1982).

The management strategy influences the forage nutritive value since it interferes in the plant maturity to be harvested. Negative changes in forage quality occur with increases in the rest period, which affects the use of forage by the grazing animal (Nave et al., 2010). The grazing method should allow the consumption of leaves before senescence occurs, in order to obtain the best nutritional value of the plant with the minimum losses due to grazing.

Over time, the plant reduces leaf and increases stem production, decreasing the nutritive value, as well as increasing senescence at the tussocks basal stratum due the shading in the lower parts of the canopy (Hodgson, 1990; Sheaffer et al., 2000). There is also a decrease in the number of tillers due to reduced light availability in lower strata canopy (Sbrissia & Da Silva, 2008).

This process is a consequence of the plant growth. With the increasing of leaf area index (LAI) over time, the number of leaves that will intercept the incident radiation enhance until reaching 95% light interception (LI) values. After that point, the shading at the bottom leaves caused by the upper increase significantly. It reduces the net forage accumulation rate (Hay & Walker, 1989). This effect is a result of the long rest period in grazing strategies with LI greater than 95% that can alter the structure of the canopy as a consequence of light competition, increasing the of stems and dead material (Pedreira et al., 2009). Changes in canopy structure associated with physical damage caused by animals can result in high losses during the grazing process and reduce harvesting efficiency (Carnevali et al., 2006).

Nave et al. (2010) studied xaraés palisade grass under intermittent stocking with three distinct periods of rest, two of them based on the light interception (95 to 100% LI), and the third fixed days (28days). The strategy based on 95% LI promoted a higher proportion of leaves and a lower proportion of stems. Forage from pastures managed with 95% of LI showed higher CP content and the stems presented lower NDF and FDA content. Moreover, the leaves and stems presented higher digestibility (IVDMD).

Tonato et al. (2014) with black oats and annual ryegrass under intermittent stocking, and grazing strategy based on 95% LI and fixed rest period (30days), registered that in ryegrass pastures managed with 95% LI the proportion of leaves is larger and the proportion of stems is lower.

In Tanzania grass pastures, smaller leaves and total forage accumulations were observed when the grazing strategy was 90% LI. This suggests that before the 95% LI the production is limited by the suboptimal incidence of light and after 95% LI the losses by senescence and dead is the limiting factor (Barbosa et al., 2007).

Pastures of ipyporã grass managed with grazing frequency based on target management (95% LI) showed higher leaves proportion and lower stem and dead material proportion in pre-grazing, when compared to lower grazing frequency (100% LI). As well as, higher content of CP and IVDMD and lower NDF content in leaves. Lenient grazing residue (15 cm post-grazing stubble) provide more leaf and with less stem than intensive grazing (10 cm post-grazing stubble) in the forage allowance (Echeverria et al., 2016).

Pedreira et al. (2017) proposed to evaluate the qualitative indicators in basilisk grass under two frequencies (95 to 100% LI) and two grazing intensities (5 and 10 cm post-grazing stubble). At high grazing intensity associated with 95% LI, the results indicated higher IVDMD of the whole forage and the leaf component. However, independently of grazing frequencies, at low grazing intensity (10 cm), the IVDMD was higher for both components (whole forage and leaf). The forage harvested, in both grazing intensities managed with 95% LI, presented higher CP content.

Difante et al. (2009), studied Tanzania grass under intermittent stocking with two defoliation intensities (residue heights of 25 and 50 cm) associated with target management (95% LI pre-grazing). Authors reported lower levels of CP (54 g.kg⁻¹) and higher NDF (80 g.kg⁻¹) in the 0-25 cm stratum and the inverse in the 25-50 cm stratum, 67 and 79 g.kg⁻¹ for CP and NDF, respectively

However, longer rest periods (light interception above 95%) results in a higher forage mass, but with a higher stems and dead material amounts. It is associated with the stabilization or reduction of the leaf accumulation rate increasing the senescence process (Carnevali et al., 2006; Barbosa et al., 2007). If there is a light incidence limitation, the stem accumulation increase in order to improve light penetration reorganizing the distribution of the leaves inside the canopy.

In practice, the determination of the moment of greater availability of leaves, IVDMD, protein and, therefore, better nutritional value, can be linked with the sward height. Several researchers have established a relationship between light interception and height, which has been used as a grazing strategy for several forage species (Pedreira et al., 2009). It allow the forage supply of better nutritional value to meet the animal nutritional demands.

In this context, to the animal obtain high performance, it must have access to high quality forage, which under grazing means that a large availability of new leaves should be provided. The forage depends on leaves to maintain high yield, since they are photosynthetically efficient (Leaf & Parsons, 1981).

The leaves are the organs that has a lower decrease in nutritive value with maturity and present the higher concentration of total digestible nutrients (Pedreira & Boin, 1969; Silveira, 1971).

The amount of cell wall contained in the forage directly affects the intake and digestibility, so its quantification is important, since it can reach from 25 to 85% of participation in dry matter (Paterson et al., 1994). These factors are accelerated by environmental factors like rain, temperature or fertilization.

During stem development, the cell wall concentration in the plant increases, due to the thickening of the primary and secondary walls,

decreasing pectin and increasing cellulose, hemicellulose and lignin amounts (Jung & Engels, 2002).

Tropical climate forages have a natural ability to accumulate more cell wall constituents than temperate species (Moore & Mott, 1973). For grasses of the genus *Panicum*, cell wall values below 55% are rarely observed, above 65% are common during regrowth, and in advanced maturation stages it could reach 75-80% (Euclides, 1995).

The lignin content is one of the major changes occurring in the plant cell wall composition and it is notably the chemical component that most influences the polysaccharides digestion in the rumen. This negative impact on digestion can occur by the toxic effect of lignin on the ruminal microbiota, physical impediment caused by the binding with the polysaccharide, which limits the access of the fibrolytic enzymes to the specific carbohydrate and hydrophobicity that also restricts the action of hydrophilic enzymes (Jung & Deetz, 1993). Furthermore, forage *in vitro* dry matter digestibility (IVDMD) is directly influenced by the lignin concentration (Casler, 2001).

However, there is a decrease in the forage nutritive value with increase in maturity (Costa & Oliveira, 1994; Costa et al., 1994b) or higher rest period due to the lower leaves shading, which causes senescence and production decreasing after 42 days (Couto, 1994). The balance between forage production and quality should be prioritized, ensuring the animals nutritional requirements as well as the pastures persistence (Costa, 1998).

Evaluating Massai guineagrass with different grazing heights (35, 40, 45 and 50 cm), Emerenciano Neto et al. (2017) verified a linear increase in leaf mass with increasing grazing height. However, there was also an increase of 312 and 597 kg ha⁻¹ in the contents of stems and dead material with the increase of 15 cm in the grazing height.

Pinto et al. (1994) reported a decrease in leaf:stem ratio for guineagrass (*Panicum maximum* Jacq.) as the regrowth age increased from 14 to 56 days, with ratio of 1.3 and 0.7, respectively. Similarly, Andrade (1987) evaluating Tobiatã guineagrass found leaf:stem ratio of 2.0 of 56 days of regrowth.

Abreu et al. (2004), evaluating the leaf:stem ratio at growth intervals (14, 28, 42 and 56 days) in *Brachiaria humidicola*, showed that up to 14 days the ratio was low due to the short period for leaves formation. However, after 14 days, values of leaf:stem ratio increasing up to 28 days, at which point the inflorescence appeared, leading to reductions in the proportions. The same authors observed the effect of the rest period for CP contents, with levels of 70 and 54 g.kg⁻¹, respectively, for 28 and 56 days of regrowth.

Gonçalves (1985) studying *Brachiaria humidicola* found similar results with 82 and 72 g.kg⁻¹ of CP, respectively, for plants with 35 and 63 days of regrowth.

The digestibility of tropical climate grasses (C4) is generally lower than those of temperate climate (C3) (Van Soest, 1982). The forages digestibility in the tropical climate is around 550 to 600 g.kg⁻¹ and may decrease if the crude protein concentration is in the range of 40 to 60 g.kg⁻¹ (Moore & Mott, 1973). Although the cell wall can be digested by the rumen microorganisms, actually this does not occur completely. Thus, fiber is used as a negative qualitative index in forage evaluations (Euclides, 1995).

Pequeno et al. (2015) evaluating three cultivars of forage species (Mulatto II e Marandu palisade grass e Tifton 85 bermudagrass) submitted to two cut intervals (28 and 42 days) in the rainy season, verified reductions in CP around 13 g.kg⁻¹ and increase of 27 g.kg⁻¹ in the neutral detergent insoluble fiber (NDF) contents.

Camarão et al. (1984) determining the contents of the cell wall constituents *Brachiaria humidicola*, at three harvesting ages, obtained 725; 743 and 764 g.kg⁻¹ for NDF, respectively, for 35, 65 and 95 days of regrowth. It should be emphasized that during the experimental period, the increase in the cell wall proportion may be due to flowering, since during this period occurred structural changes.

Costa et al. (2007), studying with *Brachiaria brizantha* cv. Xaraés with different harvest intervals (15, 20, 30, 60 days), registered that as longer as the regrowth period higher were forage accumulation and the NDF and ADF contents. However, the inverse can be observed in CP content, and P, Cu and Fe concentrations.

Grazing forage stratum: importance and use in the modulation of animal nutrition

The way in which forage is available to the animal is known as sward structure and it is ultimately responsible for the amount of nutrients ingested under grazing. Under this perspective, the grazing management means offer food to the animal in a structure that potentiates its grazing actions (Carvalho, 2001).

Forage intake and leaf:stem ratio interfere directly with animal production, especially when the protein, mineral and other nutritional factors of forage are adequate. In order to work with a particular forage species and obtain a high level of animal production is necessary to understand that the stage of developments determines the sward morphology and structure, as well as animal performance (Blaser, 1988).

The fractionation of the forage accumulated in strata (Figure 1) and its separation in components such as leaf, stem and dead material is a tool to

characterize the forage available for grazing, being able to better describe the morphological and physiological changes due to the growth and development of forage plants (Ramos, 1997). In addition, management decisions that affects the efficiency of utilization and conversion into animal product maintains close relation with the morphophysiological characteristics. Variations in the sward structure and forage allowance influence the animal responses through its effects on the amount and nutritive value of the intake forage.

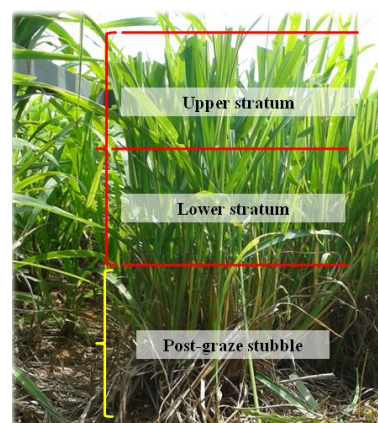


Figure 1: Fractional forage canopy in upper stratum and lower stratum

Thus, in order to ensure a high nutritional forage value, it is suggested that the animals with the highest production potential and consequently more intake demanding graze the upper strata of the plant (Figure 1), and the bottom forage strata should be destined to animals with lower nutritional requirement (Hodgson, 1990).

In pastures, the grazing action associated with the forage phenotypic plasticity, tends to increase the forage mass in strata close to the soil through the time (Garcia, 1995). Add to this the fact that the animal defoliation is highly responsive to sward structure. The animals have preferences for certain components, for example: leaves in relation to the stems (L'Huillier et al., 1986). When submitted to different types of structure, the cattle preferably graze plants with low stem, as well as with young leaves that are easily to be manipulated, due to the easy rupture, lower NDF and higher nitrogen contents (O'reagain & Mentis, 1989).

Dairy cows managed in rotational grazing produced on average 42% more milk, when they were first grazers, consuming about 50% of the forage available for grazing. The best performance in these conditions was due to the higher intake of dry matter (17% higher) in relation to the on-farm animals (Blaser et al., 1969).

Parsons et al. (1994a) concluded that the vertical structure is more decisive than horizontal in determining the selection of diets by grazing animals.

Bueno (2003), using the stratum of mombaça guineagrass, subdividing into three distinct parts, denominating basal, medium and upper strata, found that the mineral matter content was higher in the basal stratum (121 g.kg^{-1}) and median (122 g.kg^{-1}), and lower in the upper stratum (108 g.kg^{-1}). The CP content was higher in the upper and middle and lower strata in the basal stratum, 117 and 83 g.kg^{-1} , respectively. The NDF content was higher in the basal stratum (705 g.kg^{-1}) and lower in the upper stratum (663 g.kg^{-1}). For the ADF content, there was no difference between the strata. The IVDMD was lower in the basal stratum (512 g.kg^{-1}) and the same in the upper and middle stratum (544 g.kg^{-1}).

Nave et al. (2014), in a study with fescue grass, subdivided the available stratum for grazing into four parts: 5-15 cm, 15-25 cm, 25-35 cm and 35-45 cm, characterizing the vertical distribution of the nutritional value on the forage canopy during the regrowth period. In general, the lower layers of the canopy presented higher NDF content and dead material. The upper stratum presented higher IVDNDF. The upper stratum of the forage canopy consists mainly of leaves, with a lower proportion of stems. The leaves, generally, have smaller amount of fibrous constituents in relation to the stems, reporting better digestibility.

Evaluating leaf and stem distribution in four vertical strata (0-30, 30-60, 60-90 and 90-120 cm in height) of *Pennisetum purpureum* cv. Cuba under grazing, Fortes et al. (2011) also verified higher proportions of leaves and smaller shoots and dead material in the upper strata, regardless of the rest period (30, 60 and 90 days).

In study evaluating changes in sward structure in response to grazing management at two post-grazing heights (30 and 50 cm), associated with 90 cm pre-grazing height in Mombaça guineagrass, Euclides et al. (2018), verified in vertical distribution, higher leaf content and leaf: stem ratio in the upper strata. This provided forage with higher CP content and in vitro organic matter digestibility.

This same effect is observed in forage legumes. Silva et al. (2017) evaluating the grazing intensity (5, 10, 15 and 20 cm height) in forage peanut grasses (*Arachis pintoi* cv. Belmonte) during autumn and spring verified that the upper half of grass height was composed mainly of leaves and the other half of stem and dead material, regardless of the intensity. However, in pastures managed with 15 to 20 cm was observed a higher proportion of weeds.

In addition to presenting different proportions of leaves, stem and dead material, the stratum interferes in the forage harvest by the animals. Benvenuti et al. (2016), evaluating silvopastoral system with *Axonopus catarinenses* pasture in a consortium with *Pinus elliottii* under

three forage offers (low, medium and high) and in three strata (upper, middle and lower), observed that the greatest forage allowance (FA) provided a leaf percentage in the upper stratum equal to the treatment with low FA and lower than the average FA. However, a higher stem proportion were observed in the basal stratum for high FA. In addition, the percentage of CP in all strata for the low FA was higher. The utilization level of the upper grazing stratum (as a proportion of total pasture area) was 93, 91 and 96% for low, medium and high FA treatments, respectively. This corresponded to the equivalent of 7, 9 and 4% of the total area that remained without grazing.

Amaral et al. (2013), in study of four sward-management strategies defined by a combination of two pre (25 and 15 cm) and two post-grazing sward heights (10 and 5 cm) in annual ryegrass pasture (*Lolium multiflorum*) about short-term intake rate (STIR) by dairy cows, observed that treatment combined 25-10 allowed the animals to collect more herbage with a greater bite mass and, thus, resulted in a greater STIR.

Final considerations

The management of grazing has a strong influence on the forage qualitative indicators, as well on the phenotypic plasticity.

The nutritive value varies between the vertical strata of the forage canopy, which can drive grazing management based on nutritional requirements.

Thus, decisions of grazing frequency and intensity should be taken in synergy to the animal requirements in pastoral systems. It should be based in harvest efficiency, respecting physiological and structural parameters of the forages, and behavior and nutritional parameters of animals.

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