Fitting linear vs. non linear regression to sucrose accumulation in sugarcane

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Introduction The lack of forage availability during dry season is a constant challenge to maintain livestock production in tropical grassland areas. In Brazil, sugarcane has been employed mainly to sugar and ethanol industry purposes. Currently, this forage source has trigging an increase interest among dairy and beef farmers due to the high productivity (over 100 t ha^{-1}) in the same period as forage shortage in pastures. Soluble carbohydrate fraction, especially stalk sucrose contents is the most important nutrient associated with sugarcane feed value because of the poor quality of fibrous fraction. Therefore, knowledge about how sugar accumulation dynamics occurs is crucial. The objective of this research was to compare mathematical models in order to predict crop harvesting start point.

Materials and Methods Whole sugarcane plants (IAC 86 2480 variety) were collected from field plots in Ribeirão Preto, SP, Brazil (22°12'S, 47°52'W) during crop growing phase (2^{nd} cut): 150, 180, 210, 240, 270, 300, 330 and 360 days after harvesting (DAH). Two sucrose measures were considered: a) apparent sucrose content (POL), which is commonly used in sugar industry and b) ethanol soluble carbohydrates (SC) according to the methodology proposed by Hall (2000). Three regression models were considered for sucrose accumulation: a) quadratic, b) broken-line, and c) logistic. Quadratic model is the most widely spread model used in sugar industry to describe sugar curves, especially at ripening phase. Broken-line is a linear regression procedure that is simple, fast and reliable and is commonly employed in others animal nutrition research fields, ex. prediction of amino acid requirements. Logistic model (non linear) fits better when phenomena describes a sigmoid growth (non linear) and the inflection point of variable in study is closer to 50% of the maximum pool predicted (Winsor, 1932). Harvesting criteria in the mathematical models were defined as: 1) quadratic: as the point of maximum accumulation, 2) broken-line: when asymptote was matched and 3) logistic: at 95% arises of maximum predicted sucrose accumulation. GLM (quadratic) and NLIN (broken-line and logistic) procedures of SAS were performed to establish the sucrose accumulation curve. Models adjustments were compared by R^2 and RMSE (root of mean square error).

Results and Discussion As expected, POL was a more reliable measure comparing with SC due to the highest R^2 and lowest RMSE values (Table 1), probably because other soluble compounds were present in SC fraction (Hall, 2000). In addition, more variability was observed in SC database. Pattern of predicted maximum sucrose pool was maintained across measures: broken-line (earliest) followed by logistic and quadratic models (latest) (Figure 1). Although quadratic harvesting point predictions were closer between POL and SC, but these values did not reflect plant biological significance in terms of growth and ripening crop phases. Based on the present data set, sugarcane harvesting could start around 9^{th} month of regrowth. Therefore, based on POL and SC respectively, broken-line and logistic regressions are suitable tools to determine physiological maturity of sugarcane.

Conclusion Broken-line and logistic regressions are suitable tools to determine harvesting start point of sugarcane for animal nutrition.

References

Hall, M.B. 2000. Neutral detergent-soluble carbohydrates nutritional relevance and analysis. Florida: University of Florida, 42p. (Bulletin, 339).

Winsor, C.P. 1932. The gompertz curve as a growth curve. Proceedings of the National Academy of Sciences. 18:1–8.

Table 1. Mathematical models to predict sucrose accumulation in sugarcane

Model	Measure	Parameter			R^2	RMSE
		a	*b*	*c*		
Quadratic	POL	-11.094	0.163	-0.0003	0.68	1.68
$Y = a + bx + cx^2$	SC	-31.464	0.499	-0.0008	0.61	5.93
		l	*u*	*r*		
Broken-Line†	POL	14.387	-0.069	248.2	0.69	1.36
$Y = l + u(r - x_{lr})$	SC	44.766	-0.283	221.0	0.57	4.65
		a	*c*	*k*		
Logistic	POL	14.815	-3.586	0.024	0.67	1.39
$Y = a / [1 + exp (c - kx)]$	SC	46.448	-3.848	0.027	0.61	4.56

† By definition r - x_{lr} is zero when x> r

POL: apparent sucrose content; SC: ethanol soluble carbohydrates

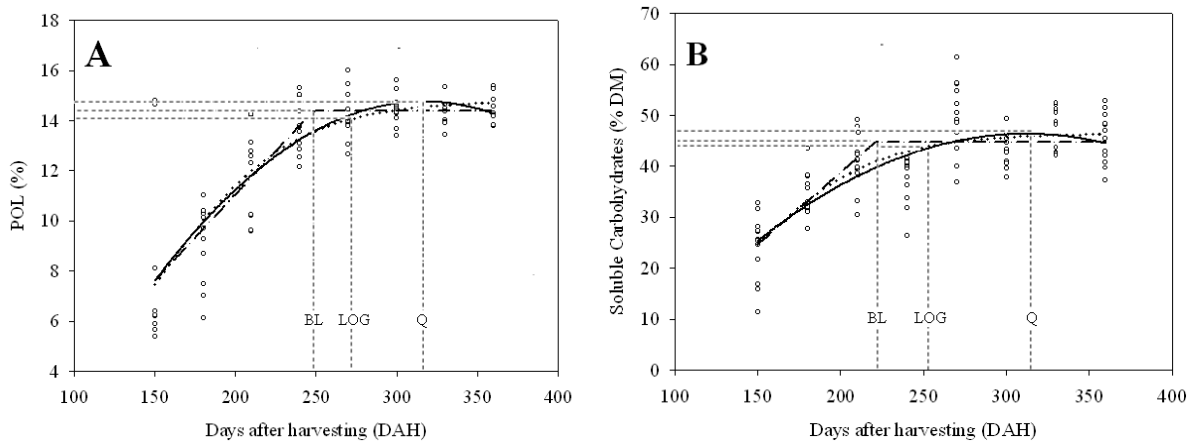

Figure 1. Sucrose accumulation curves according to quadratic (Q), broken-line (BL), logistic (LOG) models. (A) POL. (B) Soluble Carbohydrates.