ENERGETIC EFFICIENCY OF AN AGRICULTURAL TRACTOR IN FUNCTION OF TIRE INFLATION PRESSURE

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ABSTRACT: The tire inflation pressure, among other factors, determines the efficiency in which a tractor can exert traction. It was studied the effect of using two tire inflation pressures, 110.4 kPa in the front and rear wheels, 124.2 kPa in the front wheel and 138 kPa in the rear wheels, the energetic efficiency of an agricultural tractor of 147 kW of engine power, in the displacement speed of 6.0 $km.h^{-1}$, on track with firm surface, with the tractor engine speed of 2000 rpm. For each condition of the tire pressure, the tested tractor was subjected to constant forces in the drawbar of 45 kN and 50 kN, covering 30 meters. It was used a randomized complete block with a 2x2 factorial arrangement (tire pressure and drawbar power) with four replications, totaling 16 experimental units. Data were subjected to analysis of variance, using the Tukey test at 5% probability for comparison averages. The lowest hourly and specific fuel consumption, the lowest slippage of the wheelsets and the highest efficiency in the drawbar was obtained with the tire inflation pressure of 110.4 kPa in the front and rear tires of the tractor, highlighting that lower pressures improve energetic and operational performance of the tractor.

KEYWORDS: Fuel consumption, slippage, traction test.

EFICIÊNCIA ENERGÉTICA DE UM TRATOR AGRÍCOLA EM FUNÇÃO DA PRESSÃO DE INFLAÇÃO DOS PNEUS

RESUMO: A pressão de inflação dos pneus, entre outros fatores, determina a eficiência com que um trator consegue exercer a tração. Estudou-se o efeito da utilização de duas pressões de inflação dos pneus 110,4 kPa nos rodados dianteiros e traseiros, 124,2 kPa nos rodados dianteiros e 138 k Pa nos rodados traseiros , na eficiência energética de um trator agrícola de 147 kW de potência no motor, na velocidade de deslocamento do trator de 6,0 $km.h^{-1}$, em pista com superfície firme, com rotação do motor do trator em 2.000 rpm. Para cada condição de pressão dos pneus, o trator ensaiado foi submetido a forças constantes na barra de tração de 45 kN e 50 kN, percorrendo 30 metros. Utilizou-se o delineamento experimental em blocos ao acaso, com um arranjo fatorial de 2x2 (pressão dos pneus e força na barra de tração), com quatro repetições, totalizando 16 unidades experimentais. Os dados foram submetidos à análise de variância, aplicando o teste de Tukey a 5% de probabilidade, para a comparação das médias. O menor consumo horário e específico de combustível, a menor patinhagem dos rodados e o maior rendimento na barra de tração foram obtidos com a pressão de inflação dos pneus de 110,4 kPa nos pneus dianteiros e traseiros do trator, evidenciando que pressões mais baixas melhoram o desempenho energético e operacional do trator.

PALAVRAS-CHAVE: Consumo de combustível, patinagem, ensaio de tração.

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INTRODUCTION

Tractor tire sets are one of its most important components, it has the function to get balance, shifting and steering the tractor effort, (BARBOSA et al., 2005). Studying the use of high pressure tire inflation, it was concluded that there was a reduction of approximately 3 to 5% work capacity and a significant increase between 10 and 25% of fuel consumption per hectare, even in conditions of good tire adherence, as reflected in the range of 7 to 15% slippage registered (SERRANO, 2008). SMERDA & CUPERA (2010) state that the reduction in inflation pressure and the use of the right type of tires may improve the traction force and consequently decrease fuel consumption.

According to SERRANO et al. (2009), the use of high inflation pressures of the tires lead to a reduction (3% to 5%) in the work rate and a significant increase in the fuel consumption per hectare (10% to 25%) even in good traction conditions. The ASABE (1999) reports that, in firm soil, the best performance occurred when the tractor slippage is between 8 and 10%.

According to MONTEIRO et al. (2011), for different models of tractors, the average efficiency on the drawbar may vary depending on the relationship between the weight of the tractor and the engine power. MASIERO (2010) noted that in different soil surfaces, the maximum average efficiency of the drawbar power varied depending on the model, tractor power and the relationship between the weight and the engine power.

Evaluating the conditions of the soil surface (firm ground, prepared soil and vegetal cover soil), GABRIEL FILHO et al. (2010) concluded that these interfere with the ability of the tractor to develop traction, since most of the parameters related to the performance showed statistically significant variations throughout the trials.

LOPES et al. (2005) compared the performance of an agricultural tractor 4x2 TDA 89 kW (121cv) according to the type of tire (radial, diagonal and low pressure), the ballasting condition (with and without water in the tires) and four speeds (V_1 = 1.8 km h^{-1}, V_2 = 3.1 km h^{-1}, V_3 = 4,5 km h^{-1}, V_4 = 5.0 km h^{-1}). The results obtained by these researchers showed advantages for tractors equipped with radial tires.

When the motor rotates at a certain speed, the values obtained by dividing the power drawbar with those power on the power outlet, it gets several transmission efficiencies and the average between them; in possession of this information, we have indexes that represent the energetic efficiency of tractors (SILVEIRA & SIERRA, 2010).

MONTEIRO et al. (2009) who studied different levels of liquid ballast in radial tire, concluded that the lowest values of slippage and hourly fuel consumption is given for standard ballast of 37.5%

MATERIAL AND METHODS

The experiment was conducted at the Experimental Farm Lageado, belonging to the Faculty of Agricultural Sciences - FCA, São Paulo State University- UNESP, Botucatu, Brazil, and the tests were performed in the Center of Testing Agroforestry Machines and Tires, from the Department of Agricultural Engineering, on track with firm surface with a length of 400 meters long and 20 meters wide, totaling 8,000 m^2. The track had slope of 0.3% in the lengthwise. The soil of the experimental area was classified by EMBRAPA (1999) as Nitossolo dystrophic Red and water content of the soil at the time of the test was 25.4%. The geographical coordinates of the experimental track area are: 22 º 51'39 "S, 48 º 25'37" W and altitude of 770m.

All tests were performed with a tractor 4X2 TDA 147 kW of engine, at 2000 rpm, with auxiliary front wheel drive traction on.

To measure the mass of the tractor was used a platform scale; brand J-Star Electronics Model 6000, with a capacity of 30 KN and accuracy of 1%, to determine the individual weight of each tire. The tractor tires such for the rear wheeled as for the front wheeled were the type LPHF (Low

Pressure and High Fluctuation) with dimensions of 850/50-38 in the rear wheeled and 660/60-30.5 in the front wheeled. The tests were carried out with tire inflation pressure of 110.4 kPa (16 psi) in the rear and front wheeled (condition 1) and 138 kPa (20 psi) in the rear wheeled and 124.2 kPa (18 psi) in the front wheeled (condition 2), with 0% liquid ballast in the front tires and 50% of liquid ballast in the rear tires for both conditions evaluated, as recommended by the tire manufacturer. The total weight of the tractor properly ballasted was 112.4 kN.

To obtain the drawbar force in the bar of the tractor was used Mobile Unit Essay on the Drawbar - MUEDB belonging to NEMPA, which operated as a dynamometer car instrumented as described by MONTEIRO et al. (2007) and GABRIEL FILHO at al. (2008).

Inside the MUEDB, it was installed an instrumentation workbench to accommodate a PLC (programmable logic controller), and a PC laptop. The drawbar force values were obtained from a load cell SODMEX brand; model N400, with a sensitivity of 2.16 mV/V and nominal scale of 100 kN. This cell was installed in the MUEDB header to allow controlling the traction force during the displacement of the mobile unit depending on desired force for the tests.

The determination of the slippage of the tractor four wheels was obtained using pulse generators; model GIDP-60-U-12V, with a frequency of 60 pulses per turn, allowing the calculation of rotation and subsequently the slippage at each wheel. To measure the hourly fuel consumption it was used a volumetric flow meter M-III, from FLOWMATE manufactured by OVAL Corporation Japan and distributed in Brazil by K&K Brazil, LSN41L8-M2 model, with a flow rate of 1 mL/pulse. It was used the experimental design in randomized blocks, with a 2x2 factorial arrangement (tire pressure and force on the drawbar) with four replications, totaling 16 experimental units.

RESULTS AND DISCUSSION

Table 1 shows the values of slippage for the different tire pressures and forces applied to the drawbar, and that the lowest values of slippage with statistical differences were obtained for the pressure of 16 psi in the tires of the tractor in the drawbar force of 45 kN. These results show that the conditions of the soil surface and the rotated contact area/soil significantly alter tractor effort, because the traction capacity is directly related to the tractor slippage. The relationship wheeled/soil causes different conditions of slippage of tractor wheeled, confirming the results reported by SERRANO (2008).

TABLE 1. values of slippage of the tractor wheels (%).

TIRE PRESSURES	STRENGTH IN THE DRAW BAR		Average	Standard Deviation
	45 kN	50 kn		
110.4/110.4 kPa (16/16 psi)	4.87 b B	8.20 a A	6.53	
138/124.2 kPa (20/18 psi)	6.42 b A	8.30 a A	7.36	1.33
Average	5.65	8.25		
Standard Deviation	1.10	0.07		
Coefficient of variation	3.73 %			

Averages with the same letter, uppercase in the column and lowercase on the line, showed no significant difference in the Tukey test (P> 0.05).

The specific fuel consumption was statistically different such for pressure variation of tractor tires as for the forces applied to the drawbar, the lower inflation pressure showed the lowest values of specific fuel consumption for both the forces applied in the drawbar, it was due to the larger wheeled/soil contact area, providing greater tractor efficiency and better energetic efficiency, as shown in Table 2, similar results were found by MONTEIRO et al. (2009).

TABLE 2. Average values of the specific fuel consumption (kg/kW*h).

TIRE PRESSURES	STRENGTH IN THE DRAW BAR		Average	Standard Deviation
	45 kN	50 kN		
110.4/110.4 kPa (16/16 psi)	0.304 b B	0.318 a B	0.311	0.01
138/124.2 kPa (20/18 psi)	0.331 a A	0.322 b A	0.326	
Average	0.32	0.32		
Standard deviation	0.02	0.00		
Coeficiente de variação	0.313 %			

Averages with the same letter, uppercase in the column and lowercase on the line, showed no significant difference in the Tukey test (P> 0.05).

The hourly fuel consumption is lower when the tire inflation pressure was 110.4 kPa (16 psi) as keeping the same trend as the obtained results for the specific fuel consumption, according to Table 3. For the force of 50 kN applied to the drawbar, the specific consumption showed higher specific fuel consumption for both pressures, this happened to the fact that in this condition the tractor slippage was higher.

TABLE 3. Average values of hourly fuel consumption (L/h).

TIRE PRESSURES	DRAWBAR FORCE		Average	Standard Deviation
	45 kN	50 kN		
110.4/110.4 kPa (16/16 psi)	31.95 b B	36.75 a A	34.35	3.39
138/124.2 kPa (20/18 psi)	38.7 a A	36.82 b A	37.76	1.33
Average	35.33	36.78		
Standard deviation	4.77	0.05		
Coefficient of variation	0.35 %			

Averages with the same letter, uppercase in the column and lowercase on the line, showed no significant difference in the Tukey test (P> 0.05).

The efficiency on the drawbar was higher for tire inflation pressure of 110.4 kPa (16 psi) on both wheelsets. As it increases the wheeled/soil contact area, reduces the efficiency on the drawbar, where the traction device are the pneumatics, the tire type, the inflation pressure and wheeled/soil contact area, has direct influence on tractor efficiency, similar results were obtained by ZOZ & GRISSO (2003).

TABLE 4. Average values of efficiency on the drawbar (%).

TIRE PRESSURES	DRAWBAR FORCE		Average	Standard Deviation
	45 kN	50 kN		
110.4/110.4 kPa (16/16 psi)	67.07 a A	66.40 b A	66.74	0.47
138/124.2 kPa (20/18 psi)	60.55 b B	65.67 a A	63.11	3.62
Average	63.81	66.04		
Standard deviation	4.61	0.52		
Coefficient of variation	1.04 %			

Averages with the same letter, uppercase in the column and lowercase on the line, showed no significant difference in the Tukey test (P> 0.05).

ACKOWLEGMENTS

The lowest hourly and specific fuel consumption was obtained with the inflation pressure of the tires of 110.4 kPa (16 psi) in the front and rear tires of the tractor, showing that lower pressures improve energetic and operating performance of the tractor.

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