THE IMPACT OF NOISE IN THE CABIN OF AN AGRICULTURAL TRACTOR ON THE OPERATOR'S HEALTH DURING WORK WITH A FRUIT TREE SHAKER

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Abstract

The paper explores the influence of noise within the cabin of an agricultural tractor on the health of the operator during the operation of a semi-trailed fruit tree shaker. The research aims to determine the noise levels at various rotations of the power take-off shaft during the mentioned agro-technical operation and assess the potential negative impact on the operator's health. Noise measurements were conducted on agricultural fields at the Barica Sabo Family Farm using two tractor models (John Deere 6110 MC and Hurlimann XT-910.4) in accordance with the prescribed standards HRN ISO 6394 and HRN ISO 5131. Measurements were taken on both the left and right sides of the operator in both tractor cabins under operational conditions, using equipment provided by Metrel, specifically the Multinorm MI 6201 EU device with the corresponding sound probe (Class B microphone). The highest equivalent continuous A-weighted sound level (LAeq) was measured during the operation of the power take-off shaft at 500 rpm for both tractors on the right side (John Deere, 76.7 dB) and the left side (Hurlimann, 77.2 dB). Furthermore, the highest time-averaged maximum sound level (LAFmax) was measured on the left side of the Hurlimann tractor at 79.7 dB at 500 rpm. It was determined that the measured noise levels did not exceed the permissible exposure limit values: L(EX,8h) = 87 dB(A), upper cautionary exposure limits: L(EX,8h) = 85 dB(A) and lower cautionary exposure limits: L(EX,8h) = 80 dB(A). Although the highest measured value (79.7 dB) is close to the lower cautionary limit (80 dB), it is assumed that the operator of the investigated tractors is not exposed to negative noise-related health effects.

Keywords: *noise, health, safety, agricultural tractor, operator, fruit tree shaker*

1. INTRODUCTION

Hearing perceives and interprets sounds through the transmission of vibrations caused by sound waves into the inner ear, converting them into nerve impulses. Sound waves travel through the external auditory canal, causing the eardrum to vibrate. These vibrations are transmitted by the auditory ossicles in the middle ear to the cochlea, where fluid movement generates bioelectric potentials that are sent to the brain via the auditory nerve. On the basilar membrane are the sensory cells of the auditory organ of Corti, which form one row of inner and 3-4 rows of outer cells, and which have hairs on their tips. By vibrating the basilar membrane and sensory cells, the hairs bend, which creates bioelectric potentials, which in the form of nerve impulses go to the brain through the fibers of the auditory nerve. The same impulses, which come mainly from internal cells, begin to be analyzed already in the lower parts of the brain, but only in the auditory cortex of the cerebrum are they fully processed and experienced as the sensation of hearing (Hearing 2013 – 2024).

Noise is any unwanted sound, which doesn't necessarily have to be loud but is unwelcome. Noise can negatively impact the operator by causing blood pressure disturbances, hearing damage, digestive disorders, and either temporary or permanent hearing loss (Noise in the workplace 2012). Noise also reduces the operator's concentration by causing irritability and fatigue, thereby decreasing productivity, which is crucial in crop cultivation due to optimal deadlines for each crop (Barač et al. 2024). Authors Kerns et al. (2018) conducted research using the 2014 National Health Interview Survey, finding that workers exposed to noise had higher incidences of hypertension, elevated cholesterol, and hearing problems. Among surveyed workers, 19% had hearing issues, 24% had hypertension, and 58% had elevated cholesterol.

Vallone et al. (2016) stated that increased noise levels necessitate the use of personal protective equipment like earplugs, both in tractors with and without cabs. Factors affecting tractor noise levels include the type of surface, working hours, and tractor maintenance.

The research is based on the collected data of the measured noise level of 50 tractors manufactured since 1981. The obtained results indicate that tractors manufactured before 1991 have an higher noise, while tractors manufactured after 2001 have less noise. Tractors manufactured before the year 2000 generally produce a lower noise level, and this mostly depends on the insulation of the cabin. Spectral analysis of noise levels shows that low-frequency noise (16-125 Hz) is dominant in tractor cabins (Butkus et al. 2015). Authors Rubio-Romero et al. (2018) conducted research in an olive oil factory. Noise is measured for 10 years in order to obtain an analysis of the increase or decrease of noise through the progress of technology. The research found that in 2004, workers had higher signs of deafness than 63%, while in 2008, signs of deafness amounted to 55%. The noise has decreased with the introduction of machines of a newer year of production, and the authors believe that if there is a need to create a larger amount of oil, the old machines will be active, which would have a negative effect on the health of the workers.

Polivaev et al. (2018) measured noise at power plants with and without noise attenuators. The obtained data indicate that the muffler reduced the noise emission towards the environment from 7 to 11 dB(A), while at the workplace in the factory the noise level decreased from 3 to 5 dB(A) compared to without the muffler. Noise is a big problem in agricultural work, it is a problem not only for the operator but also for other workers on the farm. The aim of the research was to design a noise reduction system, taking into account that the space under the tractor engine cover is limited spatially. After reshaping the exhaust muffler, i.e. building the prototype, it was tested in the laboratory and a reduction in noise at frequencies from 400 to 600 Hz was determined (Piana et al. 2018).

A study was carried out regarding the measurement of the noise level during the operation of diesel engines with several types of diesel fuel (diesel, biodiesel and ethanol-biodiesel). Furthermore, the exhaust gas noise at maximum load is lower by 3.6 dB(A) with ethanol-biodiesel fuelcompared to the other two fuels, but the engine power is also lower by 4.5 to 5.7 % (XU and Huang 2018). The aim of the research was to examine the noise emitted from a diesel engine, Perkins A63544, with the addition of water to the fuel in percentages of 2, 5, 8 and 10%. The engine ran at 1600 to 1900 rpm. It was found that the noise increased at higher engine revolutions, and adding water to the fuel did not significantly change the noise produced (Seifi et al. 2016).

Prescribed exposure limit values and exposure warning values during an eight-hour working day and the following levels of peak sound pressure values is The Rulebook on the Protection of Workers from Exposure to Noise at Work (NN 148/2023):

- Exposure limit value: L (EX, 8 h) = 87 dB (A) and p (peak) = 200 Pa (140 dB) in relation to the reference sound pressure of 20 μPa);
- Upper warning exposure limit: L (EX, 8 h) = 85 dB (A) and p (peak) = 140 Pa (137 dB in relation to the reference sound pressure 20 μPa);
- Lower warning limit of exposure: L (EX, 8 h) = 80 dB (A) and p (peak) = 112 Pa (135 dB in relation to the reference sound pressure 20 μPa).

The research aims to determine the noise levels at different rotations of the cardan shaft during fruit harvesting operations and assess the potential negative health impacts on the operator. The hypothesis is that increased rotations will lead to higher noise levels inside the tractor cabin.

2. MATERIALS AND METHODS

The research was conducted during the agrotechnical fruit harvesting operation using a Weremczuk Maja shaker, combined with two tractors: John Deere 6110 MC and Hurlimann XT-910.4, at various PTO speeds (300 rpm, 400 rpm, and 500 rpm). Measurements were conducted in the cherry orchard at OPG Sabo following the standards HRN ISO 6394 and HRN ISO 5131. Table 1 provides the technical specifications of the John Deere 6110 MC tractor.

Engine power (kW)	82
Max. Engine power (kW)	86.5
Max. Power on cardan shaft (kW)	64.1
Max. torque (Nm)	480
Number of cylinders/volume (Nr/cm^3)	4/ 4500
Forward/reverse speeds	16/12
Front axle suspension	TLS
Cabin suspension	/
Fuel tank volume (l)	193
Tractor mass (kg)	5007
Tires; front/back	380/85R28/460/85R38
Length (cm)	448
Width (cm)	255
Number of working hours (h)	714
Height with cabin (cm)	287
Year of manufacture	2016

Table 1. Technical characteristics of the John Deere 6110 MC tractor

Source: TractorData 2016, John Deere 6110MC, viewed 13 May 2024, <http://www.tractordata.com/farm-tractors/008/9/8/8985-john-deere-6110m-dimensions.html>

The technical specifications of the Hurlimann XT-910.4 tractor are shown in Table 2. It is the second tractor in the study that was aggregated with a shaker.

Engine power (kW)	76.8
Max. Engine power (kW)	76.8
Max. torque (Nm)	380
Number of cylinders/volume (Nr/cm^3)	4/ 4000
Forward/reverse speeds	20/ 20
Front axle suspension	No
Cabin suspension	No
Fuel tank volume (l)	140

Tractor mass (kg)	3980
Tires; front/back	13.6R28/16.9R38
Length (cm)	411
Width (cm)	237
Number of working hours (h)	9532
Height with cabin (cm)	271
Year of manufacture	2004

Table 2. Technical characteristics of the Hurlimann XT 910.4 tractor

Source: TractorData 2004, Hurlimann 910.4 XT, viewed 13 May 2024, <http://www.tractordata.com/farm-tractors/002/8/6/2861-hurlimann-9104-xt-dimensions.html>

The Weremczuk Maja shaker was attached to the tractor at two points, specifically at the ends of the ore. The left and right lower tractor levers secured the ore, ensuring the working height of the attached machine. The machine operation requires the tractor's PTO shaft, to which the shaker's cardan shaft, secured with protective plastic, is connected. This protective plastic ensures safety by preventing extremities from getting caught, as five people, including the operator, are needed to carry out the fruit harvesting operation. Two hydraulic hoses connected to the tractor are used to turn the two wheels located at the rear of the fruit shaker. The technical data of the fruit shaker are shown in Table 3.

Picking capacity (ha/ h)	0.20-0.25
Average harvest value (%)	95
Drive	Obtained from a tractor
Collection of fruit large/small boxes (lbs)	1100 / 20-40
Hydraulic system	Independent hydraulic working drive
Time required for one tree (min)	1-1.5
Min. required power (KS)	35
Tree diameter (cm)	8-25
Help when turning	Control of the rotation of the rear wheels
The width of the tarp (m)	4, 5, 6
Required number of workers in working with large boxes	4

Table 3. Technical data of Weremczuk Maja

Source: Weremczuk agromachines 2017, Weremczuk Maja, viewed 26 April 2024, <https://weremczukagro.com/en/products/automatic-fruit-shaking-machine/>

According to the HRN ISO 6394 standard, measurements were taken on the left and right sides of the operator while the tractor was stationary, with the PTO shaft at the specified RPMs and the shaker under constant load, including all moving parts like the 'hand for the cherry' As per HRN ISO 5131, the device must be positioned relative to the reference point of the operator's seat, from the center of the operator's head to the level of the seat at a height of 790 ±20 mm and 200 ±20 mm from the center of the head on both sides. Measurements were taken with a Metrel noise measuring device, type Multinorm MI 6201 EU, with an associated sound probe (class A microphone).

The data processed in the measurement and presented in graphs and tables are marked with the following symbol:

- LAeq – time averaged or equivalent continuous sound level, measured in both channels. It is the most important and widely used metric, representing the mean sound level over the entire measurement period.

Further statistical processing will include descriptive statistics and analysis of variance.

3. RESULTS

The processed and analyzed data are presented in the following graphs and tables.

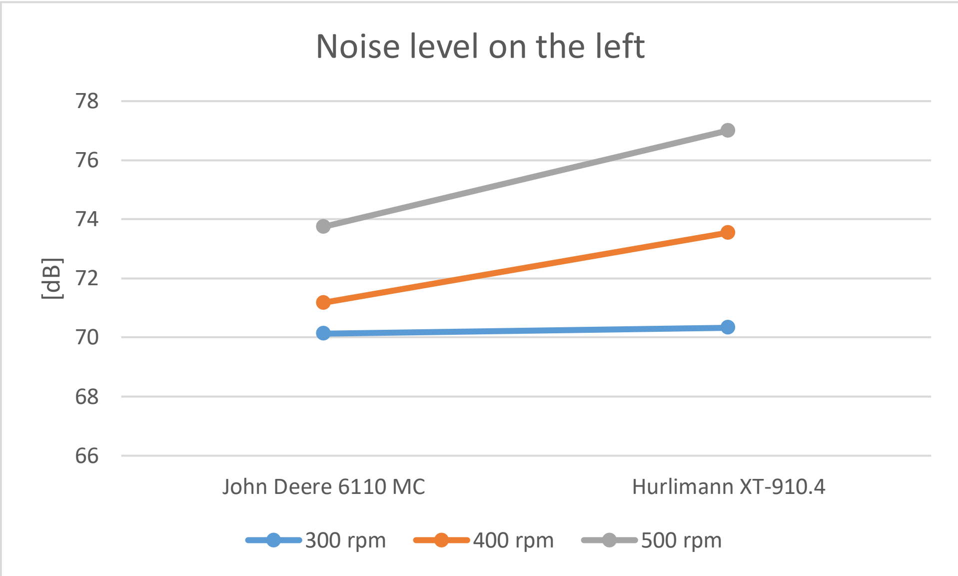

Fig. 1. Average noise values inside the tractor cab on the left side

Fig. 1 shows that the older Hurlimann XT-910.4 tractor produced a higher noise level at all three power take-off (PTO) speeds. It is also evident that the noise level of both tractors aggregated with the fruit shaker increases with the PTO speed. The highest measured noise level for both tractors was at 500 rpm PTO, with the Hurlimann XT-910.4 tractor producing 3.26 dB(A) more noise than the John Deere 6110 MC tractor.

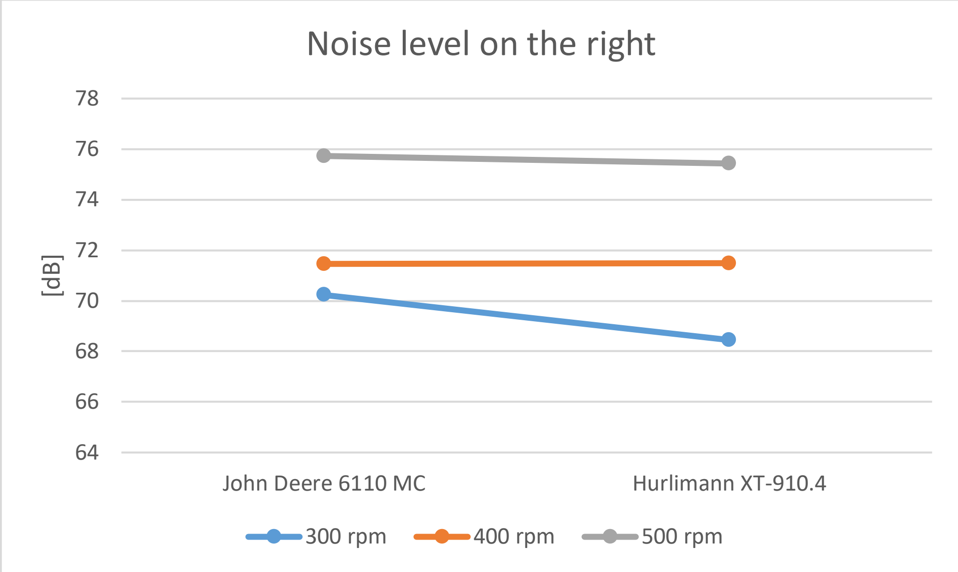

Fig. 2. Average noise values inside the tractor cab on the right side

The newer tractor emitted a higher noise level compared to the other tractor, producing more noise at 300 and 500 rpm PTO, while at 400 rpm PTO, the Hurlimann tractor produced 0.3 dB(A) more noise (Fig. 2).

Comparing both tractors, Fig. 1 and 2 show that the John Deere tractor produced more noise on the right side of the cabin than on the left, likely due to the design and attachment of the exhaust pipe.

Rpm PTO	N	Mean LAeq [dB(A)]	σ	C.V. %	Std. Error	95% Confidence Interval for Mean		Min.	Max.
						Lower bound	Higher bound		
300	12	70,233	0,1875	0.2669	0,0541	70,114	70,352	70,0	70,5
400	12	72.367	1,2463	1.7221	0,3598	71,575	73,159	71,1	74,0
500	12	75,383	1,7146	2.2745	0,4949	74,294	76,473	73,6	77,2
Total	36	72,661	2,4524	3.3752	0,4087	71,831	73,491	70,0	77,2

Table 4. Descriptive statistics of mean values measured on the left side

Descriptive statistics of the mean values of measured noise on the left side (Table 4) showed the largest standard error at 500 rpm PTO.

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	160,696	2	80,348	53,232	0,000
Within groups	49,810	33	1,509		
Total	210,506	35			

Table 5. Analysis of variance on the left side (ANOVA)

Table 5 shows that there was a statistically significant difference in the mean noise levels among the observed tractors, as determined by the analysis of variance.

Rpm PTO	N	Mean LAeq [dB(A)]	σ	C.V. %	Std. Error	95% Confidence Interval for Mean		Min.	Max.
						Lower bound	Higher bound		
300	12	69,342	1,1619	1.6756	0,3354	68,603	70,080	68,4	71,2
400	12	71,925	0,5610	0.7799	0,1620	71,569	72,281	71,0	72,5
500	12	75,583	0,4951	0.6550	0,1429	75,269	75,898	75,2	76,7
Total	36	72,283	2,7101	3.7492	0,4517	71,366	73,200	68,4	76,7

Table 6. Descriptive statistics of mean values measured on the right side

Descriptive statistics of the mean values of measured noise on the right side (Table 6) revealed the highest standard error at 300 rpm PTO.

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	236,062	2	118,031	185,403	0,000
Within groups	21,008	33	0,637		
Total	257,070	35			

Table 7. Analysis of variance on the right side (ANOVA)

The analysis of variance among the observed tractors, shown in Table 7, revealed a statistically significant difference in the mean noise levels.

4. DISCUSSION

Authors Taş et al. (2018) by measuring the noise of forestry workers (pulling, felling and loading wood) found that they are exposed to noise that exceeds the permissible limit of 87 dB(A) according to NN 148/2023. Moreover, the recorded values ranged from 85 to 105 dB(A), contrary to the findings of this study. According to the authors, excessive noise is attributed to a poor environment with makeshift equipment, specifically agricultural machinery known for generating high noise levels.

Two tractors were included in the study, one with 3000 working hours and the other with 6000 working hours, with negligible differences in measured noise. When working on different soils, the noise differences were large and amounted to differences of 7 dB, it is important to note that not a single value exceeded the permitted limits, as in this research (Vallone et al. 2016). A similar study of noise measurement was carried out by the authors Barač et al. (2017) on the Landini powerfarm DT100A tractor when moving on different agrotechnical surfaces, where they state that not a single measured value exceeded the permissible limit, as in this research. Furthermore, the same authors and Barač et al. (2016a) state that the mean value of noise obtained by descriptive statistics is higher for younger tractors, which partially coincides with this research on the right.

Authors Barač et al. (2016b) conducted research in Belje d.d., where they measured noise on three Fendt model 410 tractors. Research on the three mentioned tractors was conducted over three years (2010, 2013 and 2015). The measurements were carried out in accordance with the prescribed standards for measuring the noise produced by the tractor in the environment. The results of the measurements showed that the oldest tractor produced the highest level of noise, and what is partly similar to the present study, none of the values exceeded the permissible limits. Research conducted by Barač et al. (2018) where noise was measured at the operator's workplace at different engine revolutions of 1100 rpm, 1800 rpm and 2200 rpm over three years indicate that increasing them increases the level of noise produced, which is the same as in this research. Furthermore, Jahanbakhshi et al. (2020) state in their research where noise was measured at two types of rpm with two types of exhaust that the noise level is higher at higher engine revolutions, which is the same as in this research. The authors of De Souza and others. (2023) conducted a noise measurement study on two New Holland TL85E and Massey Ferguson 265 tractors at 5 rpm (1,500, 1,700, 1,900, 2,100, and 2,300 rpm). Furthermore, they state that the hypothesis that the noise level will increase with an increase in the number of revolutions has been fully confirmed, which is the same as in this research.

5. CONCLUSIONS

Conclusions drawn from the conducted research are as follows:

- None of the measured values exceeded the permissible limit of 87 dB(A), including the lower warning limit of 80 dB(A), indicating regular maintenance of the tractor by the OPG owner.
- The hypothesis that increasing PTO rpm increases noise levels in both tested tractors was confirmed.
- Descriptive statistics of mean noise values indicate highest readings at 500 PTO rpm on both the left and right sides of the operator in agricultural tractors.
- Analysis of variance revealed a statistically significant difference in mean noise values between the left and right sides of both tractors.
- Fig. 2 shows that the older tractor (Hurlimann) produced lower noise levels on the right side at 300 and 500 PTO rpm, except for 400 PTO rpm where it was 0.3 dB(A) higher, negligible given the device's accuracy, likely due to better consolidated exhaust pipes compared to the newer tractor. On the left (Fig. 1), the John Deere tractor consistently produced significantly lower noise levels across all PTO rpms compared to the Hurlimann tractor.

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