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IMAGE: OBSERVATORY WITH STAR TRAILS ON MOUNTAINS FOR CLEAR SKY

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Njabulo Eugene Dlamini

ABSTRACT

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Effects of Soil and Variety on Sugarcane Ratoon Yields

Njabulo Eugene Dlamini

ABSTRACT

Sugarcane cultivation in many industries happens under diverse soil conditions, and soils are known to influence the productivity of sugarcane varieties. The purpose of this study was to assess the impact of soil types on the yields of different sugarcane varieties to inform variety selection strategies. Data (cane yield, TCH; sucrose yield, TSH; sucrose content) from three variety trials established on three different soil types (well draining, WDS; moderately draining, MDS; poorly draining, PDS), comprising eight varieties, and collected over six successive crops (plant cane and five ratoons) were used for this study. The data were subjected to a linear mixed model to assess the relative contribution of variance components to yield variability across ratoon crops. Linear and quadratic regressions were used to evaluate yield trends across ratoon crops. Soils significantly impacted ratoon crop yields, with the rate of yield decline (TCH and TSH) increasing with decrease in drainage abilities of the soils. Significant differences in varieties' ratooning ability and soils' effect therefore highlighted an opportunity to select varieties that are adapted to specific soil conditions, hence benefiting from genetic gains. Greater soil type impact than variety on variation in ratoon crops' yield emphasized the need to adopt best management practices aimed at improving soil hydraulic characteristics rather than relying only on improved varieties.

Keywords: soil type sugarcane varieties ratoon yield.

Author: Eswatini Sugar Association Technical Services, P. O. Box 367, Simunye, Eswatini.

I. INTRODUCTION

Sugarcane [*Saccharum* sp.] is an important commercial crop predominantly grown in tropical and subtropical areas as a source of sugar. It supplies about 86% of the world's sugar and the remaining 14% is produced from sugar beet [*Beta vulgaris* L., Chenopodiaceae] (OECD-FAO, 2019). Besides the production of sugar from the sugarcane stalk, there are other valuable by-products that are derived after the extraction of sucrose at the mills such as bagasse and molasses. Bagasse is the fibrous portion of sugarcane that remains after the removal of the juice, and in many industries, it is used to generate electricity for milling operations, estates and the excess may be exported to the national electricity grid. Molasses is the thick syrupy residue left after the abstraction of sucrose from the clarified sugar juice (syrup). It is utilized to produce alcohol and its by-product named vinasse (or condensed molasses soluble) is used as fertilizer for sugarcane fields.

The profitability of sugarcane (*Saccharum* sp.) production is largely dependent on the availability of varieties that are adaptable and high yielding across diverse growing conditions over several ratoon crops. The ability of a variety to sustain profitable yields over several ratoon crops is termed ratooning ability (RA) (Chapman et al., 1992; Ferraris et al., 1993; Milligan et al., 1996). RA is a desirable trait for improved economics in sugarcane production (Farrag et al., 2019), and in many sugarcane growing countries, high RA is a prerequisite for commercializing a variety. Past studies have reported significant differences in RA of sugarcane varieties (Ricaud and Arceneaux, 1986; Chapman et al., 1992; Ramburan et al., 2009; Zhou and Shoko, 2012; Masri and Amein, 2015; Chumphu et al., 2019), indicating that RA is genetically influenced. This therefore presents sugarcane breeders and agronomists with an opportunity to simultaneously select for both high yield and RA in sugarcane development programmes.

Ratoon yields in sugarcane production are affected by several factors including the variety grown (RA) and the soil type on which it grows. Apart from fertility, another essential characteristic of a soil that affects sugarcane yields is its hydraulic properties. This is consistent with findings of previous studies (Chapman et al., 1992; Henry and Ellis, 1996; Kingston, 2003; McGlinchey and Dell, 2010; Marin *et al*., 2019). However, these studies and others, have looked at the effect of soil on yields in isolation. Information on how different sugarcane varieties' ratoon yields are impacted by soil types is scanty. In many sugarcane industries, variety trials are run over three crops (i.e., plant crop and two ratoons) making it hard to appreciate how soils affect yields beyond the second ratoon crop.

The objective of this study was to: (i) assess the RA of released sugarcane varieties, (ii) determine the relative effect of soil types and varieties on sugarcane ratoon yields, and (iii) ascertain the impact of soil types on RA.

II. MATERIAL AND METHODS

2.1 Datasets

Data for this study were sourced from three sugarcane variety trials conducted by the Eswatini Sugar Association (ESA) at three sites namely Simunye, Big Bend and Mhlume representing well draining (WDS), moderately draining (MDS) and poorly draining (PDS) soils, respectively (Figure 1). Details of the soil classification are given in Table 1. Figures 2 and 3 show climatic data for these areas for the seven year period (2015-2021) of the study. During the period 2015 – 2016, the industry experienced a severe drought resulting in water rationing across all areas. In the year 2021, tropical cyclone *Eloise* provided above-normal rainfall in all three areas.

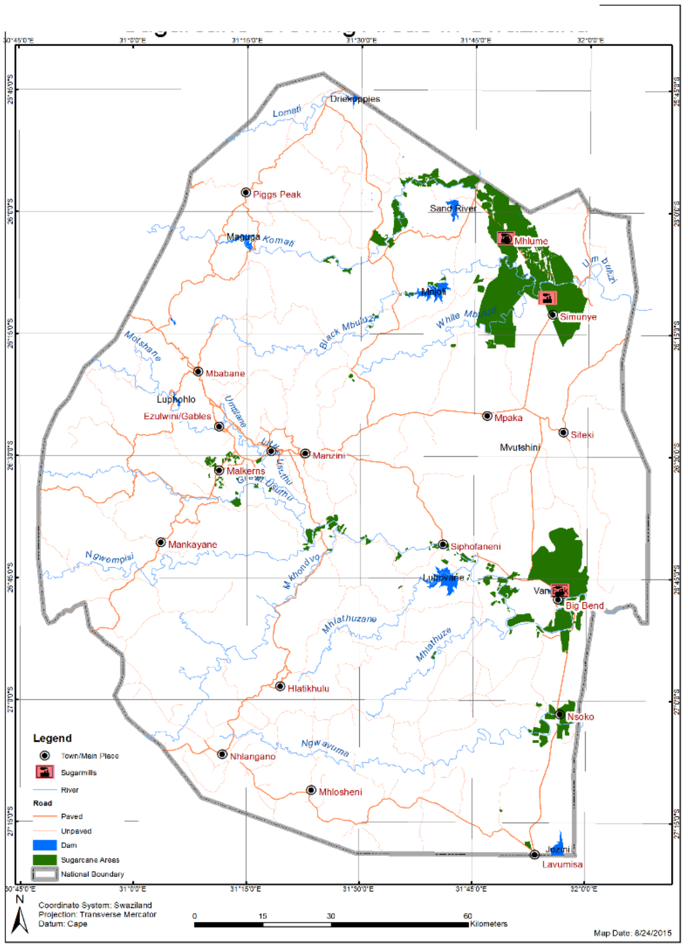


Figure 1: Map showing sugarcane growing areas and sugar mills of Eswatini.

The trials were planted in August 2015, and data were collected over six successive crops (plant crop *plus* five ratoon crops). All three trials were planted with eight varieties (i.e., N23, N25, N36, N41, N46, N49, N53 and N57) imported from the South African Sugarcane Research Institute (SASRI) (Table 2). The Simunye trial had plots with five rows each that were 10 meters long and 1.9 meters apart. The Big Bend trial plots had five rows each that were 12 meters long and 1.8 meters apart, and the Mhlume trial had four rows per plot that were 17 meters long with inter row spacing of 1.5 meters. All trials were established as randomized complete block design with six replications per site. The trials were managed as per estate standard practices including fertilizer applications, irrigation and weed control.

A day before cutting, the cane was burnt to remove extraneous matter as per industry practice. The cut cane was topped (i.e., removal of the topmost vegetative section of cane stalks) according to estate practice, which is below the natural breaking point, and placed in bundles. The weights of the bundles of cane from the net rows were measured using a digital scale mounted on a tractor-operated hydraulic boom. The cane yield per plot was then transformed to a per ha basis. After weighing, a total of 16 stalks per plot were randomly sampled from the bundled cane to determine cane quality parameters such as sucrose content (SUC, %), brix, purity, and fiber content at the laboratory using standard protocol explained by Shoonees-Muir et al. (2009). The secondary trait, tons sucrose per hectare (TSH), was calculated as a product of tons cane per hectare (TCH) and SUC.

2.2 Data analysis

Statistical analyses for this study were conducted using GenStat® 23rd Edition statistical software (VSN International, 2023). To establish the relative effect of variety and soil type on sugarcane ratooning for each trait, the data from the three trials were combined and the following linear mixed model was fitted:

$$Y_{ijkl} = \mu + S_i + R(S)_{ij} + V_k + VS_{ik} + VR(S)_{ijk} + C_l + CS_{il} + CV_{kl} + CR(S)_{ijl} + SVC_{ikl} + E_{ijkl} \quad (1)$$

Where, Y_{ijkl} is observation for k^{th} variety, in the i^{th} soil type, k^{th} replication nested within the i^{th} soil type, in crop-year l; μ is the overall mean; S_i is the effect of the i^{th} soil type; $R(S)_{ij}$ is the random effect of the j^{th} replication nested within the i^{th} soil type; V_k is the effect of the k^{th} variety; VS_{jk} is the interaction effect of the k^{th} variety and i^{th} soil type; $VR(S)_{ijk}$ is the random interaction effect of the k^{th} variety and the j^{th} replication nested within the i^{th} soil type; C_l is the effect of the l^{th} crop-year; CS_{il} is the interaction effect of the l^{th} crop-year with i^{th} soil type; CV_{kl} is the interaction effect of the l^{th} crop-year and k^{th} variety; $CR(S)_{ijl}$ is the random interaction effect of the l^{th} crop-year and the j^{th} replication nested within the i^{th} soil type; SVC_{ikl} is the interaction effect of the i^{th} soil type, k^{th} variety and l^{th} crop-year; and E_{ijklm} is the residual term.

Table 1: Land classes and soil types in the Eswatini sugar industry (sourced from Nixon *et al.* 1986).

Land Class	Sets/Series	Description	Soil type
I	R, N, L sets	• Deep, red, well structured • Medium to heavy textured • Free draining	Well draining
II	W, B, F sets, Daputi series	• Moderate to weak structure • Deep, light textured • Excessively draining • Mainly of alluvial origin	Well draining
III	S set	• Shallow, well structured • Medium to heavy texture • Freely draining	Well draining
IV	T, D sets (excluding Daputi series)	• Moderate structure • Medium to heavy texture • Imperfectly draining • Moderately deep	Moderately draining
V	K, C, V sets	• Deep • Blocky or cracking clays • Moderate to poor drainage	Moderately draining
VI	Z set, Homestead series	• Thin topsoil (often absent) • Coarsely structured subsoil • Inherent salinity/sodicity problems • Poorly draining	Poorly draining
VII	E, O, P, J, G, H sets (excluding Homestead series)	• Coarsely structured topsoil • Abrupt change to heavy, poorly drained subsoil • High salinity/sodicity risk	Poorly draining

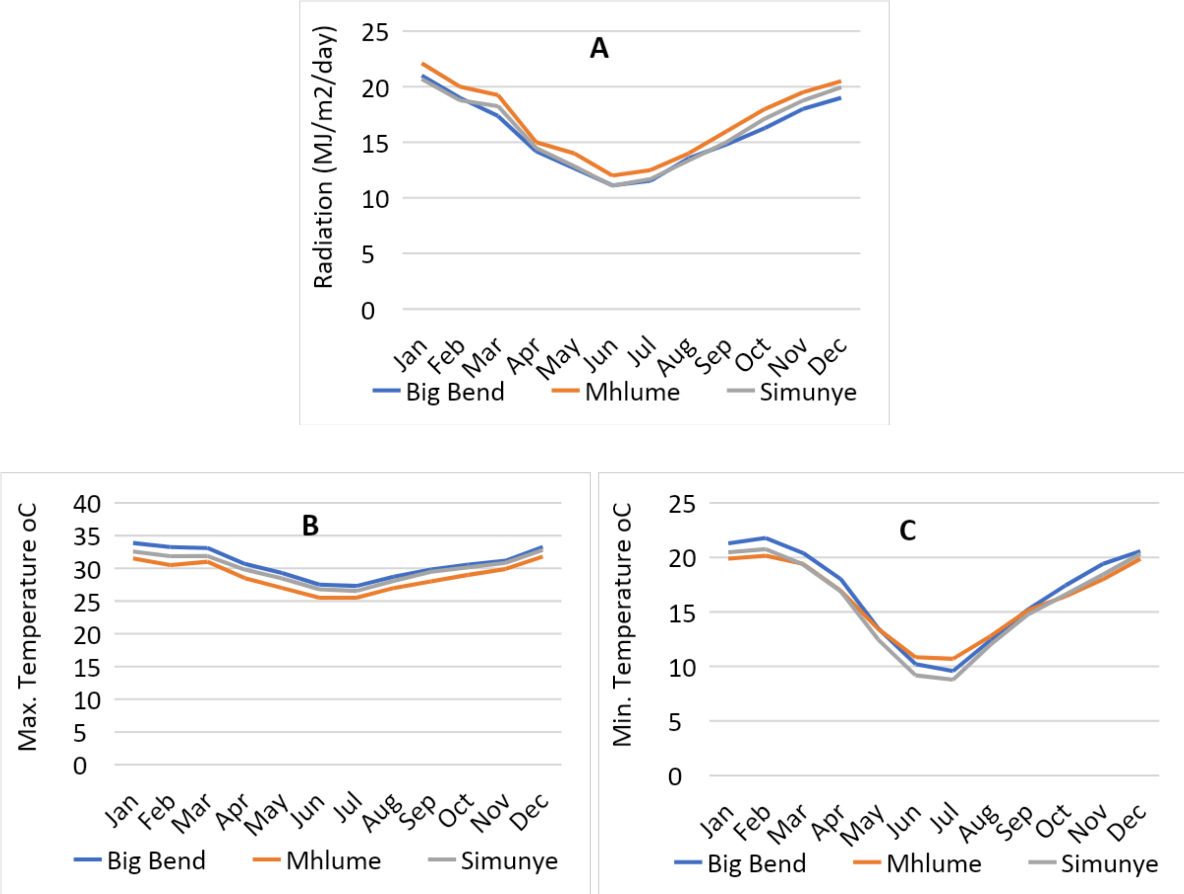


Figure 2: Average monthly solar radiation (A), maximum temperature (B) and minimum temperature (C) trends recorded during the study period (2015 – 2021) for the three trial areas (Mhlume, Simunye and Big Bend)

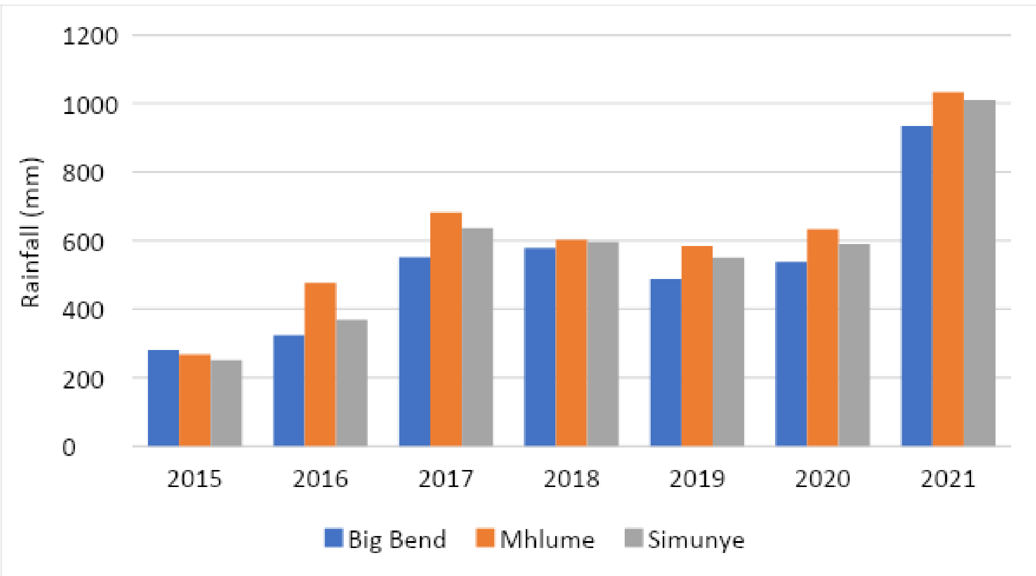


Figure 3: Cumulative annual rainfall received in the three trial areas (Mhlume, Simunye and Big Bend) during the study period (2015 – 2021)

Table 2: Parentage, origin and year of release of the eight varieties used in this study.

Variety	Parentage	Origin	Year of release
N23	NCo376 x N52/219	SASRI, South Africa	1992
N25	Co62175 x N14	SASRI, South Africa	1994
N36	82F1225 x 78Z1635	SASRI, South Africa	2000
N41	77F0790 x 82W1542	SASRI, South Africa	2002
N46	97F2857 x Unknown*	SASRI, South Africa	2007
N49	87E1331 x N30	SASRI, South Africa	2008
N53	89F1649 x 88F1903	SASRI, South Africa	2011
N57	N25 x Unknown*	SASRI, South Africa	2013

*SASRI: South African Sugarcane Research Institute; *: parent is unknown*

Simple linear regression was conducted to estimate intercepts and slopes of the different yield traits across ratoon numbers:

$$Y_{im} = \alpha_i + \beta_j C_m + \varepsilon_{im} \quad (2)$$

where compare Y_{im} is the yield of variety i in ratoon crop m; α_i is the intercept predicting plant cane yield of variety i; β_j is the slope of yield of variety i; C_m is ratoon crop number m; and ε_{im} is the random error.

To compare the variety trends across ratoon crops, quadratic curves were fitted for the different traits for each variety. The quadratic model was of the form:

$$Y = Ax^2 + Bx + C, A \neq 0 \quad (3)$$

where, Y is cane yield at ratoon crop x; A is the quadratic coefficient (it indicates whether the curve opens upward or downward. When positive, the curve is opening upward and when negative, the curve is opening downward. The absolute value of this coefficient also indicates whether the curve is narrow or wide); B is the linear coefficient (it indicates a slope of the curve which is a measure of ratooning ability); and, C is the intercept (the yield of the plant cane crop i.e., the first crop). The quadratic model was chosen because it gave a substantially better fit than the linear model. The results were presented in graphical form.

III. RESULTS

3.1 Yield traits' values

The summaries of the data of three traits are presented in Tables 3 to 5. The plant cane at the PDS had a larger mean TCH than the plant cane on WDS and MDS (Table 3). However, the rate of TCH decline across ratoon crops was larger in the PDS compared to the other two sites. The MDS had a larger TCH decline than WDS. The coefficient of variation (CV%) for TCH data ranged from 9.2% (plant cane) to 13.8% (third ratoon) indicating that the quality of data was acceptable. According to Gomes (2009), for field experiments, if CV% is below 10%, the data quality is considered very good; between 10% and 20%, the data quality is considered good; between 20% and 30%, it is said to be low; and above 30%, it is considered very low.

The MDS had significantly lower average SUC than the other sites for the plant cane, third and fifth ratoon crops (Table 4). There were no distinct patterns of SUC change across ratoon crops for the three sites indicating that this trait was stable across the test crops. The CV% for SUC data ranged from 3.7% (third ratoon) to 6.0% (plant cane) indicating a low variability in the data.

TSH trends across ratoon crops were similar to those of TCH, suggesting that TCH had a greater influence on TSH than SUC (Table 5). The PDS gave a larger TSH than WDS and MDS in the plant cane. However, from the second ratoon crop, TSH for the PDS was consistently below those of the other soil types. The CV% for TSH data ranged from 10.4% (plant cane) and 14.0% (third ratoon crop) indicating that the experimental data was good. The CV% for TCH and TSH were larger than those of SUC, indicating greater stability for SUC compared to TCH and TSH.

Table 3: Cane yield (tons cane per ha, TCH) trends for eight sugarcane varieties tested in three different sites across six crops (PC: plant crop; R1: first ratoon; ...; R5: fifth ratoon)

Site	Variety	PC	R1	R2	R3	R4	R5	Mean
Simunye	N23	115.2	110.1	132.6	118.6	139.6	98.3	119.1
	N25	131.9	133.3	133.0	126.1	123.2	102.8	125.0
	N36	117.7	122.7	124.7	113.5	116.3	109.1	117.3
	N41	106.1	108.6	122.3	108.5	111.7	97.3	109.1
	N46	107.9	117.8	133.9	115.3	129.9	121.2	121.0
	N49	111.4	116.4	126.6	116.8	119.5	107.2	116.3
	N53	125.5	126.4	140.3	115.0	127.0	118.4	125.4
	N57	102.6	120.9	139.2	117.3	121.2	85.4	114.4
	Mean	114.8	119.5	131.6	116.4	123.5	105.0	118.5
Big Bend	N23	108.1	143.2	137.2	115.8	94.8	74.8	112.3
	N25	105.9	145.6	142.4	113.2	107.7	94.6	118.2
	N36	100.7	128.5	124.2	112.3	98.8	83.7	108.0
	N41	95.3	128.7	130.0	100.8	86.5	75.0	102.7
	N46	92.6	136.5	138.2	113.7	121.7	118.9	120.3
	N49	103.6	120.8	141.2	112.8	105.7	97.8	113.7
	N53	109.4	139.4	136.7	111.4	112.2	103.7	118.8
	N57	99.3	139.8	138.7	93.4	59.9	71.3	100.4
	Mean	101.9	135.3	136.1	109.2	98.4	90.0	111.8
Mhlume	N23	126.0	110.5	80.7	72.2	71.4	46.9	84.6
	N25	136.9	135.9	102.1	96.5	85.9	59.5	102.8
	N36	133.9	124.0	89.2	85.6	79.8	66.8	96.5
	N41	119.5	112.5	83.8	72.5	69.4	58.2	86.0
	N46	134.9	123.9	89.2	96.4	90.8	81.4	102.8
	N49	109.2	109.5	86.5	86.9	68.7	61.1	87.0
	N53	130.0	110.2	79.8	74.2	64.5	49.8	84.7
	N57	123.8	109.6	75.2	67.4	53.5	29.4	76.5
	Mean	126.8	117.0	85.8	81.4	73.0	56.6	90.1
	LSD(5%)	12.0	14.3	14.5	16.2	13.9	12.8	14.1
	CV%	9.2	10.1	10.8	13.8	12.4	13.3	11.7

3.2 Impact of site and variety on traits performance

Table 6 presents the fixed effects of the linear mixed model (equation 1) for the three traits. The main effects of soil, variety and crop were highly significant for all three traits suggesting large impact of soil type, variety and crop number on the yield traits. Soil x variety interaction was highly significant for the three traits indicating that varieties' performance on the traits was largely affected by soil type. The two way interactions of soil x crop and variety x crop were highly significant for all three traits implying that crop yields were greatly impacted by soil types and varieties. Significant variety x crop, suggest differences in ratooning abilities of the sugarcane varieties. The three-way interaction, soil x variety x crop, was also highly significant suggesting that soil type had a large effect on ratooning abilities of the varieties for the three traits.

Table 4: Sucrose content (%) trends for eight sugarcane varieties tested in three different sites across six crops (PC: plant crop; R1: first ratoon; ...; R5: fifth ratoon)

Site	Variety	PC	R1	R2	R3	R4	R5	Mean
Simunye	N23	17.7	17.4	17.6	17.0	16.8	17.4	17.3
	N25	16.3	16.9	17.0	17.6	17.0	17.2	17.0
	N36	18.8	19.6	18.9	18.2	18.8	18.9	18.9
	N41	17.8	18.3	18.4	17.9	17.9	18.8	18.2
	N46	18.4	17.6	17.1	17.7	18.1	17.7	17.7
	N49	18.4	19.8	19.0	17.9	18.8	19.2	18.8
	N53	18.6	18.8	18.7	18.0	17.8	18.8	18.4
	N57	18.6	18.8	18.2	17.9	18.5	18.0	18.3
	Mean	18.1	18.4	18.1	17.8	18.0	18.2	18.1
Big Bend	N23	14.2	17.6	17.4	16.1	16.8	15.9	16.3
	N25	14.4	17.2	17.4	16.1	17.9	15.6	16.4
	N36	15.9	19.5	19.2	17.5	18.7	18.1	18.2
	N41	15.9	19.3	18.5	17.5	18.9	17.3	17.9
	N46	15.5	18.2	18.5	16.8	17.5	16.7	17.2
	N49	17.0	19.2	18.6	18.1	18.9	17.9	18.3
	N53	16.0	18.0	17.7	16.9	18.6	17.1	17.4
	N57	14.9	18.6	18.6	16.1	18.4	16.4	17.1
	Mean	15.5	18.4	18.2	16.9	18.2	16.9	17.4
Mhlume	N23	16.0	17.9	16.7	16.7	18.1	17.2	17.1
	N25	16.2	18.7	16.9	16.7	18.6	18.2	17.5
	N36	18.2	19.1	18.0	18.2	19.1	17.5	18.4
	N41	16.9	19.1	17.4	17.6	18.8	18.3	18.0
	N46	17.9	18.4	16.7	16.7	18.2	17.6	17.6
	N49	18.9	19.9	18.3	18.7	19.8	20.0	19.3
	N53	18.6	19.7	18.1	18.4	19.4	19.4	18.9
	N57	18.1	19.8	17.5	17.5	19.1	18.9	18.5
	Mean	17.6	19.1	17.4	17.6	18.9	18.4	18.2
	LSD(5%)	1.2	1.0	0.9	0.7	0.9	0.8	0.9
	CV%	6.0	4.8	4.4	3.7	4.1	4.0	4.6

The F-values for the main effects indicated that crop effect on the traits was larger than those of soil and variety. For TCH and TSH, soil had a larger effect than variety, while for SUC variety had a greater influence than soil. Among the four interactions, the F-values suggested that soil x crop had the largest influence on the traits' values. Variety x crop effect on TCH and TSH was greater than those of soil x variety and soil x variety x crop, insinuating that ratooning ability had a larger effect on these traits compared to the latter interactions.

Table 5: Sucrose yield (tons sucrose per ha, TSH) trends for eight sugarcane varieties tested in three different sites across six crops (PC: plant crop; R1: first ratoon; ...; R5: fifth ratoon)

Site	Variety	PC	R1	R2	R3	R4	R5	Mean
Simunye	N23	20.3	19.1	23.3	20.2	23.4	17.1	20.6
	N25	21.5	22.5	22.6	22.1	20.9	17.6	21.2
	N36	22.2	24.1	23.5	20.6	21.9	20.6	22.1
	N41	18.9	19.9	22.5	19.4	20.0	18.3	19.8
	N46	19.9	20.7	22.9	20.3	23.4	21.4	21.4
	N49	20.6	23.0	24.0	20.9	22.5	20.6	21.9
	N53	23.3	23.7	26.2	20.6	22.5	22.2	23.1
	N57	19.1	22.7	25.3	21.0	22.4	15.4	21.0
	Mean	20.7	22.0	23.8	20.6	22.2	19.2	21.4
Big Bend	N23	15.3	25.2	23.9	18.6	15.8	11.9	18.4
	N25	15.3	25.0	24.7	18.2	19.3	14.7	19.6
	N36	15.9	25.0	23.8	19.7	18.5	15.2	19.7
	N41	15.1	24.8	24.0	17.6	16.3	12.9	18.5
	N46	14.3	24.9	25.5	19.2	21.2	19.9	20.8
	N49	17.6	23.2	26.3	20.4	20.0	17.6	20.8
	N53	17.4	25.0	24.2	18.8	20.8	17.8	20.7
	N57	14.8	25.9	25.7	15.0	11.0	11.7	17.3
	Mean	15.7	24.9	24.8	18.4	17.9	15.2	19.5
Mhlume	N23	20.2	19.8	13.5	12.1	12.9	8.0	14.4
	N25	22.3	25.4	17.2	16.1	15.9	10.9	18.0
	N36	24.4	23.7	16.1	15.6	15.2	11.7	17.8
	N41	20.1	21.5	14.6	12.7	13.0	10.7	15.4
	N46	24.2	22.8	15.0	16.1	16.5	14.3	18.1
	N49	20.7	21.8	15.8	16.3	13.6	12.2	16.7
	N53	24.1	21.7	14.4	13.7	12.6	9.6	16.0
	N57	22.3	21.7	13.1	11.8	10.2	5.5	14.1
	Mean	22.3	22.3	15.0	14.3	13.7	10.4	16.3
	LSD(5%)	2.3	2.8	2.7	2.9	2.6	2.4	2.6
	CV%	10.4	10.6	11.2	14.0	12.5	13.9	12.1

3.3 Regression analysis for TCH, SUC and TSHA

Since the fixed term of soil x variety x crop was significant for the three traits, regression analysis was conducted on a per soil type basis (equation 2). The purpose was to establish how these traits change over ratoon crops for the eight varieties as influenced by soil type. Intercepts represented the plant crop yield while the slopes represented the rate of yield change across ratoon crops. The slope is a measure of varieties' RA. The more negative the slope is, the higher the rate of yield decline and vice versa. Preferred varieties (or soils) are those with higher intercepts and a slope above zero (indicating an incline) or closer to zero (indicating low rate of decline).

Table 6: Fixed effects for three sugarcane yield traits - tons cane per ha (TCH), sucrose content (SUC, %) and tons sucrose per ha (TSH).

		TCH		SUC		TSH	
	NDF:DDF	F stat	P-value	F stat	P-value	F stat	P-value
Soil (S)	2:15	73.77	<0.001	30.67	<0.001	73.28	<0.001
Variety (V)	7:105	12.28	<0.001	45.49	<0.001	11.67	<0.001
Crop (C)	5:75	146.98	<0.001	54.08	<0.001	170.03	<0.001
S x V	14:105	2.50	0.006	2.99	<0.001	2.36	0.008
S x C	10:75	58.26	<0.001	23.25	<0.001	71.63	<0.001
V x C	35:525	7.19	<0.001	2.04	0.002	6.02	<0.001
S x V x C	70:525	2.43	<0.001	1.50	0.002	2.31	<0.001
Mean		106.80		17.87		19.07	
CV%		11.70		4.60		13.90	

The different soil types had different variety rankings on TCH intercepts (Table 7). For WDS and PDS, variety N25 had the highest intercept, while variety N23 had the highest for MDS. Variety N46 had the lowest intercept on WDS and MDS, and variety N49 was the lowest on PDS. For WDS, only two (N25 and N57) of the eight varieties had significant TCH slopes while only five varieties had significant slopes for MDS. For the PDS, all eight varieties had highly significant slopes. These results suggest larger TCH decline across ratoon crops for PDS compared to the other soil types. MDS had a larger TCH decline compared to WDS.

Similar to TCH, varieties were ranked differently on SUC for the three soil types (Table 8). On WDS, variety N36 had the highest SUC intercept while variety N25 had the lowest. On MDS and PDS, variety N49 had the largest intercept while N23 had the least intercept. SUC slopes for all varieties on WDS and MDS were not significant suggesting absence of ratoon crop effects for these soils. On PDS, only variety N25 had a significant positive SUC slope indicating a large increase in SUC for the variety with advance in ratoon crop number. These findings confirm that SUC was comparatively stable across ratoon crops compared to TCH.

Varieties N53 and N57 had the largest TSH intercepts for WDS and MDS, while N25 and N36 had largest TSH intercepts for PDS (Table 9). On WDS, only varieties N25 and N57 had significant TSH slopes suggesting larger TSH decline for the two varieties compared to the other varieties. On MDS, four varieties (N57, N23, N41 and N36) had significant negative TSH slopes, while all eight varieties had significant negative TSH slopes for PDS. Similar to TCH, PDS had greater TSH decline across ratoon crops than the other soil types. MDS had a greater TSH decline than WDS. This supports previous observations that TCH had a bigger influence on TSH than SUC.

3.4 Quadratic trends for TCH, SUC and TSHA

To graphically compare the influence of soil on trends of the three traits, quadratic curves were drawn per variety per trait per soil type. For WDS and MDS, varieties' TCH trends assumed the same pattern, which were parabolic curves facing downward (Figure 4). However, MDS curves generally were narrow compared to those of WDS confirming that varieties experienced a larger decline in TCH on MDS compared to WDS. The upward movement of variety N46 within the first four crops was observed on these soil types (i.e., WDS and MDS). This observation validates the positive slopes for this variety noted in the regression analysis. While the variety had mediocre plant cane yields on both soils, its trends indicate that it has a higher RA compared to the other varieties. Variety N57, which had a larger decline in the regression analysis on WDS, showed an incline in the first three crops before assuming a steeper decline from the third ratoon crop than all the other varieties. On MDS, N57 also showed a sharper decline from the second ratoon crop together with N23. The yield gap between N46 and N57 in

Table 7: Results of regression analysis for tons cane per ha (TCH) based on ratoon crop number (plant crop and four successive ratoons) showing estimated intercepts and slopes of the regression lines and p-values of the slopes.

Variety	Well draining soil			Moderately draining soil			Poorly draining soil		
	Intercept ± SE	Slope ± SE	P-value	Intercept ± SE	Slope ± SE	P-value	Intercept ± SE	Slope ± SE	P-value
N23	119.80 ±4.57	-0.30 ±1.51	0.844	136.10 ±5.96	-9.52 ±1.97	<0.001	121.82 ±4.03	-14.89 ±1.33	<0.001
N25	138.05 ±4.57	-5.21 ±1.51	<0.001	130.70 ±5.52	-5.13 ±1.82	0.005	141.56 ±4.03	-15.50 ±1.33	<0.001
N36	122.54 ±4.57	-2.09 ±1.51	0.168	121.56 ±6.53	-6.02 ±2.16	0.006	130.25 ±4.03	-13.49 ±1.33	<0.001
N41	112.58 ±4.57	-1.39 ±1.51	0.358	121.45 ±5.52	-6.77 ±1.82	<0.001	117.93 ±4.03	-12.78 ±1.33	<0.001
N46	115.00 ±4.57	2.40 ±1.51	0.113	115.82 ±5.96	1.78 ±1.97	0.367	128.44 ±4.03	-10.27 ±1.33	<0.001
N49	117.85 ±4.57	-0.62 ±1.51	0.684	121.02 ±5.96	-2.94 ±1.97	0.137	112.85 ±4.03	-10.35 ±1.33	<0.001
N53	129.63 ±4.57	-1.68 ±1.51	0.267	129.46 ±6.53	-3.99 ±2.16	0.065	123.60 ±4.03	-15.55 ±1.33	<0.001
N57	122.06 ±4.57	-3.06 ±1.51	0.044	130.79 ±5.96	-12.16 ±1.97	<0.001	122.80 ±4.03	-18.52 ±1.33	<0.001

SE: standard error; P-value: probability value

Table 8: Results of regression analysis for sucrose content (SUC) based on ratoon crop number (plant crop and four successive ratoons) showing estimated intercepts and slopes of the regression lines and p-values of the slopes.

	Well draining soil			Moderately draining soil			Poorly draining soil		
Variety	Intercept ± SE	Slope ± SE	P-value	Intercept ± SE	Slope ± SE	P-value	Intercept ± SE	Slope ± SE	P-value
N23	17.57 ±0.25	-0.10 ±0.08	0.204	15.99 ±0.42	0.12 ±0.14	0.374	16.64 ±0.29	0.18 ±0.10	0.069
N25	16.60 ±0.25	0.16 ±0.08	0.054	16.07 ±0.39	0.23 ±0.13	0.072	16.88 ±0.29	0.26 ±0.10	0.007
N36	19.07 ±0.25	-0.08 ±0.08	0.303	17.86 ±0.46	0.14 ±0.15	0.378	18.60 ±0.29	-0.09 ±0.10	0.330
N41	17.93 ±0.25	0.10 ±0.08	0.210	17.42 ±0.39	0.18 ±0.13	0.178	17.57 ±0.29	0.18 ±0.10	0.069
N46	17.87 ±0.25	-0.05 ±0.08	0.546	17.02 ±0.42	0.07 ±0.14	0.594	17.73 ±0.29	-0.06 ±0.10	0.527
N49	18.85 ±0.25	0.00 ±0.08	0.958	18.04 ±0.42	0.10 ±0.14	0.480	18.89 ±0.29	0.15 ±0.10	0.121
N53	18.64 ±0.25	-0.08 ±0.08	0.311	16.93 ±0.46	0.15 ±0.15	0.322	18.67 ±0.29	0.11 ±0.10	0.277
N57	18.62 ±0.25	-0.11 ±0.08	0.162	16.81 ±0.42	0.13 ±0.14	0.337	18.37 ±0.29	0.04 ±0.10	0.695

SE: standard error; P-value: probability

Table 9: Results of regression analysis for tons sucrose per ha (TSH) based on ratoon crop number (plant crop and four successive ratoons) showing estimated intercepts and slopes of the regression lines and p-values of the slopes.

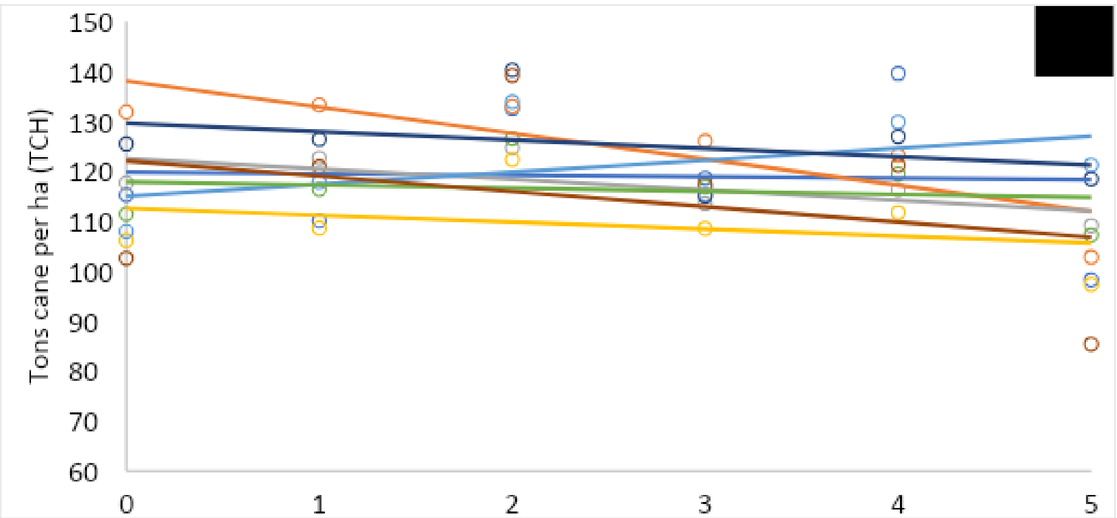
	Well draining soil			Moderately draining soil			Poorly draining soil		
Variety	Intercept ± SE	Slope ± SE	P-value	Intercept ± SE	Slope ± SE	P-value	Intercept ± SE	Slope ± SE	P-value
N23	21.05 ±0.85	-0.18 ±0.28	0.513	22.03 ±1.31	-1.44 ±0.43	<0.001	20.34 ±0.84	-2.37 ±0.28	<0.001
N25	22.97 ±0.85	-0.71 ±0.28	0.012	21.28 ±1.21	-0.62 ±0.40	0.125	24.16 ±0.84	-2.47 ±0.28	<0.001
N36	23.37 ±0.85	-0.49 ±0.28	0.081	21.92 ±1.44	-0.99 ±0.47	0.039	24.16 ±0.84	-2.56 ±0.28	<0.001
N41	20.21 ±0.85	-0.15 ±0.28	0.586	21.42 ±1.21	-1.07 ±0.40	0.008	20.75 ±0.84	-2.13 ±0.28	<0.001
N46	20.47 ±0.85	0.39 ±0.28	0.171	20.06 ±1.31	0.31 ±0.43	0.481	22.94 ±0.84	-1.92 ±0.28	<0.001
N49	22.22 ±0.85	-0.12 ±0.28	0.662	21.96 ±1.31	-0.45 ±0.43	0.300	21.46 ±0.84	-1.89 ±0.28	<0.001
N53	24.17 ±0.85	-0.42 ±0.28	0.138	22.01 ±1.44	-0.52 ±0.47	0.274	23.20 ±0.84	-2.87 ±0.28	<0.001
N57	22.69 ±0.85	-0.68 ±0.28	0.016	22.41 ±1.31	-2.03 ±0.43	<0.001	22.69 ±0.84	-3.43 ±0.28	<0.001

SE: standard error; P-value: probability the last ratoon crop was larger on MDS than on WDS. On PDS, unlike on the other soils, all varieties assumed a downward linear trend confirming the larger TCH decline on this soil type compared to the other soil types. Similar to MDS, N57 had consistently lower TCH from the second ratoon than the other varieties. On PDS, N46 had the lowest TCH decline indicating higher RA for the variety in this soil type as well.

The SUC curves were almost similar for WDS and PDS indicating stability of the trait across ratoon crops (Figure 5), with some varieties showing insignificant increases as shown in the regression analysis. On MDS, the varieties assumed a parabolic curve facing downward. The varieties demonstrated an increase from the plant cane to the third ratoon crop after which they assumed a downward trend. The varieties' TSH curves (Figure 6) simulated those of TCH supporting the prior observation that the influence of TCH on TSH was larger than that of SUC.

IV. DISCUSSION

Significant soil type effects on varieties' ratoon cane and sucrose yields were apparent in this study largely due to their hydraulic properties. Loss of yields across ratoon crops was larger on PDS compared to WDS and MDS, and MDS experienced larger losses than WDS. WDS are deep and well-structured thus providing an effective crop root habitat. MDS are well structured, however, relative to WDS they are shallow hence root growth is restricted. On the other hand, PDS are weakly-structured/duplex soils and they are characterized by prolonged periods of waterlogging especially after heavy rains. Apart from the detrimental effect of anaerobic conditions on plant growth, waterlogged conditions lead to salinity and sodicity challenges. The accumulation of salts within the root zone limits root growth and development resulting in yield losses and decline across ratoon crops.



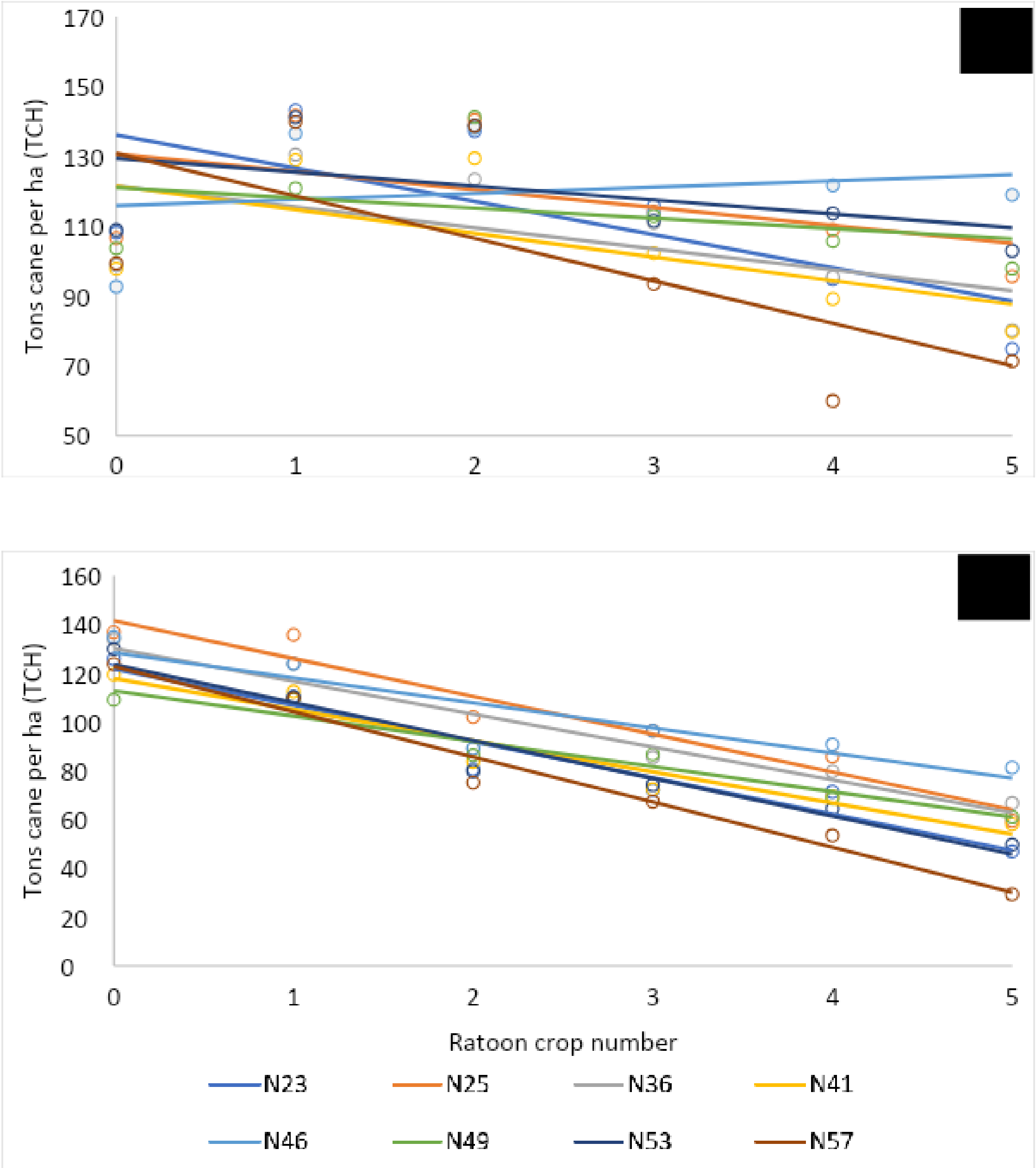


Figure 4: Quadratic cane yield (TCH) trends for eight sugarcane varieties tested on three soil types (A: well draining, WDS; B: moderately draining, MDS; C: poorly draining, PDS) harvested over six successive crops (plant cane, 0 and five ratoon crops, 1 to 5).

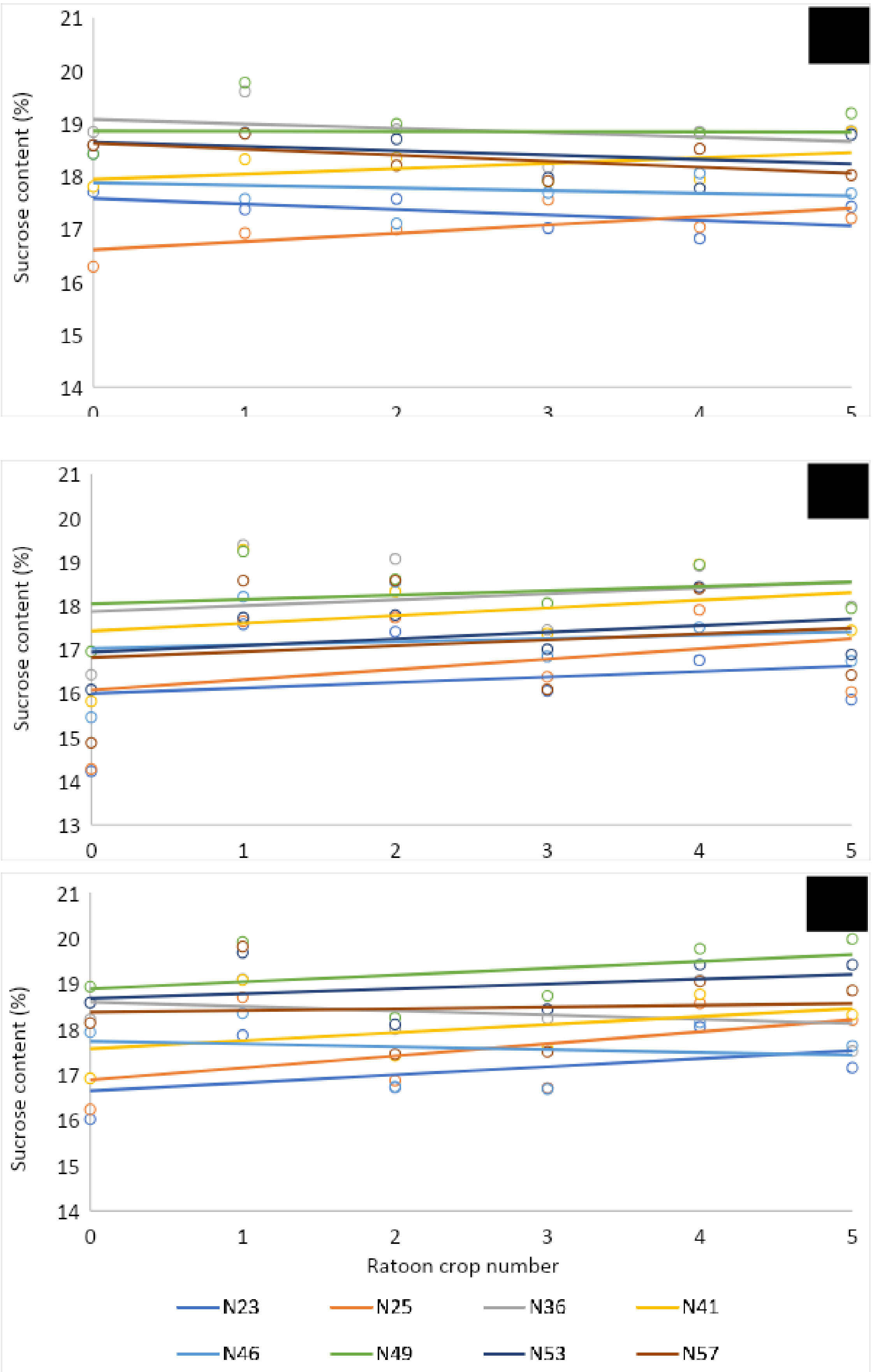


Figure 5: Quadratic sucrose content (%) trends for eight sugarcane varieties tested on three soil types (A: well draining, WDS; B: moderately draining, MDS; C: poorly draining, PDS) harvested over six successive crops (plant cane, 0 and five ratoon crops, 1 to 5).

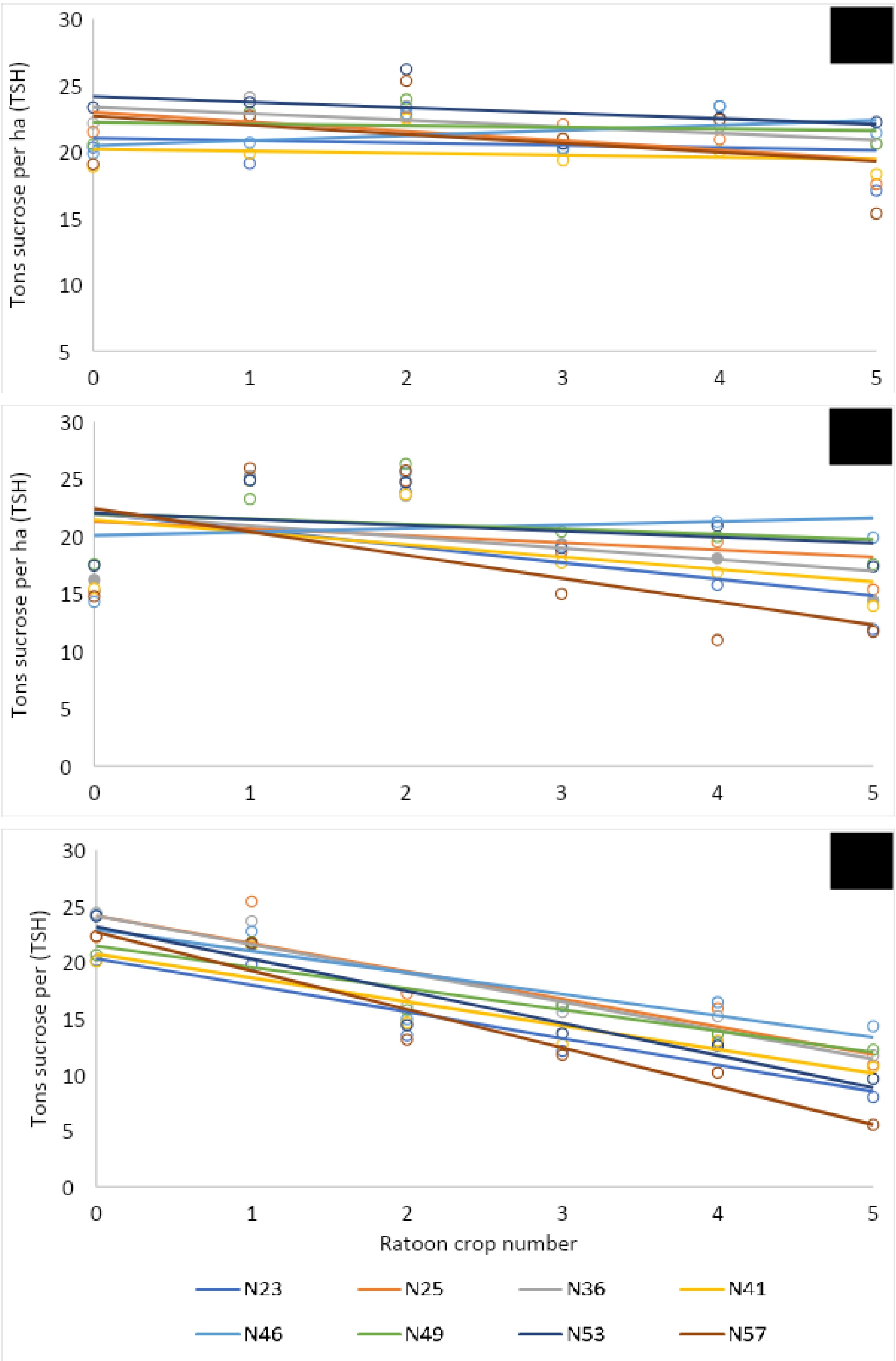


Figure 6: Quadratic sucrose yield (TSH) trends for eight sugarcane varieties tested on three soil types (A: well draining, WDS; B: moderately draining, MDS; C: poorly draining, PDS) harvested over six successive crops (plant cane, 0 and five ratoon crops, 1 to 5).

To address these challenges and improve productivity of poorly draining soils, installation of subsurface drainage pipes (especially for irrigated cane), application of gypsum (Henry and Ellis, 1996), adoption of best irrigation practices (Nixon and Simmonds, 2004), and fallowing and green manuring (Nixon, 1992) are greatly recommended.

The significant variety x crop and soil x variety x crop interactions suggested that the varieties had different ratooning abilities, and these ratooning abilities were different for the three soil types. This therefore indicated the existence of opportunity to select varieties that are adapted to the different soil conditions. Crop yields can be improved by exploiting genetic diversity whereby broadly and or specifically adapted varieties are deployed in environments where their performances are optimized. Variety N46 which had low to average yields in the plant cane, showed great stability across ratoon crops for all soil types (i.e., broad adaptation) indicating that the variety is suitable for long ratoon crop cycles. Variety N25 which had the highest plant cane yields on WDS and PDS, and N23 which was the highest on MDS are ideal for shorter ratoon cycles because of the large yield decline across ratoon crops. Previous studies (Rattey and Kimbeng 2001; Rea and Vieira 2002; Kimbeng et al. 2009; Masri and Amein 2015; Mehareb et al. 2016; Sengwayo et al. 2016) also reported significant variety x crop interactions, signifying the importance of testing for ratooning ability. This further emphasizes the criticality of evaluating new sugarcane varieties across diverse soil types.

The larger soil x crop interaction than variety x crop interaction for the studied traits suggested greater soil type effect on crop yields than variety. In other words, soil conditions had more influence on yield than variety choice. Most growers are of the perception that a good variety on its own guarantees higher and sustainable yields. This finding disputes such an idea emphasizing that soil management is critically important if good yields are to be achieved and sustained over multiple crops. Similar findings were reported by Ramburan et al. (2013). These authors suggested that to enhance ratoon yields more focus should be placed on environment manipulation through good crop management rather than focusing on varietal longevity.

The greater contribution of TCH on TSH than SUC was glaring in this study. TSH is a secondary trait, produced from the primary traits, TCH and SUC. Other studies (Milligan et al., 1990; El- Hinnawy et al., 2001; Masri et al., 2008; Abu-Ellail et al., 2019; Gravois et al., 2019) have reported similar observations, suggesting that efforts directed at increasing TCH of ratoon crops will likely lead to higher TSH. However, such efforts should not compromise sucrose content levels. At both genetic and phenotypic levels, TCH and SUC are known to be negatively correlated (Milligan et al., 1990; Jackson, 2005; Klomsa-ard et al., 2013). Maybe with the advent of advanced biotechnology tools, geneticists will assist unravel and overcome this incompatibility. TCH is highly influenced by the environment while SUC is genetically determined (Nayamuth et al., 1999, 2005; Badaloo et al., 2005; Ramburan and Zhou, 2011; Sandhu et al., 2012). TCH has a more complex genotype x environment (GEI) compared to sucrose content (Jackson and McRae, 2001). This is mainly caused by the large number of genes with small individual additive effects that control this trait (Zhou et al., 2011; Zhou, 2015). The larger effect of soil type on TCH and TSH than variety, and larger effect of variety on SUC than soil type perhaps supports this understanding. The relative stability of SUC across ratoon crops than TCH and TSH probably emphasizes the same.

The causes of the differences in SUC trends across ratoon crops for the different soil types were not obvious. WDS and PDS trends were comparable, while MDS trends were not similar to those of WDS and PDS. Beyond soil type effect, this may also be attributed to location effect. The Big Bend trial site representing MDS is located south-east of the country while the Simunye and Mhlume sites representing WDS and PDS, respectively, are both located in the north-east as shown in Figure 1.

Future studies will need to investigate these differences in SUC in-depth. This will help inform future variety tests. Location effects in the current arrangement are treated as noise or confounding factors, yet incorporating them in the analyses may assist in explaining the GEI present in the trial networks.

The larger crop effect on the three traits relative to soil and variety effects underscores the great impact of environmental conditions on yields. Multi-environment trial studies reported that the environment accounts for a larger effect on yield variation than the effects of variety and variety x environment interactions (Gauch and Zobel, 1996; Verma et al., 2006; Anley et al., 2013; Akbarpour et al., 2014). The crop-year variable indicates the effects of biotic and abiotic factors on yields of aging ratoon crops (Zhou and Shoko, 2012). The yield in a ratoon crop is largely influenced by the prevailing conditions in which the ratoon crop grows (Ramburan, 2013). A ratoon crop growing under conducive climatic conditions is expected to yield better than one growing under less conducive conditions. In this study, variation in rainfall received during the testing period as shown in Figure 3 may have had tremendous effect on the differences in the ratoon crop yields.

V CONCLUSION

This study indicated that the effect of soil types on ratoon crop yields and varieties' RA should not be ignored. The rate of yield decline increases with decline in soil quality in terms of drainage properties. To exploit genetic gains, the diversity in varietal adaptability presented an opportunity to match varieties with their ideal soil types. The larger effect of soil type on cane and sucrose yields than variety effect was a critical finding for this study, emphasizing the importance of adapting best soil management practices in sugarcane production as opposed to relying only on improved varieties. TSH is a product of TCH and SUC, and TCH proved to have a bigger contribution to TSH than SUC. With TCH and SUC gains from breeding programmes having stagnated over the years, efforts to break this stagnation are needed if TSH is to be increased in the long-term.

Conflict of Interest

The authors declare no conflict of interest

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Abbreviations:

MDS, moderately draining soils; PDS, poorly draining soils; RA, ratooning ability; SUC, sucrose content; TCH, tons cane per ha; TSH, tons sucrose per ha; WDS, well draining soils

Core ideas

- Sugarcane ratoon longevity and yields largely dependent on hydraulic properties of the soil
- Soil effect on sugarcane ratoon yields superseded variety (genetic) effect emphasizing importance of adopting good soil management practices
- Variety affected sugarcane ratoon yield, demonstrating existence of different ratooning abilities
- Cane yield made a larger contribution to sucrose yield than sucrose content

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Environmental Awareness Measured by the NEP Scale: A Case Study of Paraguay

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ABSTRACT

In Latin America in general and in Paraguay specifically, environmental problems are a great concern not only due to the loss of forests and biodiversity but, above all, due to the lack of awareness within the population about the proportions and consequences of this issue. Taking into account that the human population and its behavior towards the environment is responsible, directly or indirectly, for the majority of the acts and attitudes that cause the current environmental situation, it is of great importance to increase the number of studies in the human dimension of environmental conservation and try to determine which factors contribute to pro environmental attitudes. In this case study, the environmental awareness in a sample of 358 people who are exposed to different degrees to natural environments through their sports activities are analyzed using an instrument proposed by Dunlap and Van Liere (1978) called the New Environmental Paradigm Scale (NEP scale). A 14- item version of the instrument was used in a population that was classified into 3 groups according to the degree of contact with nature to which they are exposed through their sports activities. No significant differences were obtained in the measurements through this instrument among the groups. The structure of environmental awareness resulted in a high score for the "ecocentrism" dimension while lower scores were obtained for "awareness of the limit of resources" and "environmental anthropocentrism".

Keywords: NEP scale, ecological behavior, socio-environmental exploration, psychometric study, environmental behavior, environmental awareness.

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ABSTRACT

In Latin America in general and in Paraguay specifically, environmental problems are a great concern not only due to the loss of forests and biodiversity but, above all, due to the lack of awareness within the population about the proportions and consequences of this issue. Taking into account that the human population and its behavior towards the environment is responsible, directly or indirectly, for the majority of the acts and attitudes that cause the current environmental situation, it is of great importance to increase the number of studies in the human dimension of environmental conservation and try to determine which factors contribute to pro environmental attitudes. In this case study, the environmental awareness in a sample of 358 people who are exposed to different degrees to natural environments through their sports activities are analyzed using an instrument proposed by Dunlap and Van Liere (1978) called the New Environmental Paradigm Scale (NEP scale). A 14- item version of the instrument was used in a population that was classified into 3 groups according to the degree of contact with nature to which they are exposed through their sports activities. No significant differences were obtained in the measurements through this instrument among the groups. The structure of environmental awareness resulted in a high score for the "ecocentrism" dimension while lower scores were obtained for "awareness of the limit of resources" and "environmental anthropocentrism". These results are described as high environmental awareness measured through the NEP scale within the outdoor activity members. It is recommended that further empirical investigations to compare populations that do not participate in any of these activities be performed and also that their scores are correlated in order to determine whether outdoor activities raise awareness of the environmental problems and if they are used as a tool in environmental education in Paraguay.

Keywords: NEP scale, ecological behavior, socio-environmental exploration, psychometric study, environmental behavior, environmental awareness.

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RESUMEN

En América Latina en general y en Paraguay específicamente, los problemas ambientales son una gran preocupación no sólo por la pérdida de bosques y biodiversidad sino, sobre todo, por la falta de conciencia de la población sobre las proporciones y consecuencias de este tema. Teniendo en cuenta que la población humana y su comportamiento hacia el medio ambiente es responsable, directa o indirectamente, de la mayoría de los actos y actitudes que provocan la situación ambiental actual, es de gran importancia incrementar el número de estudios en la dimensión humana de conservación ambiental y tratar de determinar qué factores contribuyen a las actitudes pro ambientales. En este caso de estudio analizamos la conciencia ambiental en una muestra de 358 personas que están expuestas en diferentes grados a los entornos naturales a través de sus actividades deportivas *utilizando un instrumento propuesto por Dunlap y Van Liere denominado Escala del Nuevo Paradigma Ambiental (escala NEP). Se utilizó una versión de 14 artículos que se aplicó a través de formularios en línea dirigidos a la población de estudio, la cual se clasificó en 3 grupos según el grado de contacto con la naturaleza al que están expuestos a través de sus actividades deportivas. No se obtuvieron diferencias significativas en las mediciones mediante este instrumento entre estos grupos. La estructura de conciencia ambiental resultó en una puntuación alta para la dimensión "ecocentrismo", mientras que se obtuvieron puntuaciones más bajas para "conciencia del límite de los recursos" y "antropocentrismo ambientalista". Estos resultados se describen como una alta conciencia ambiental medida a través de la escala NEP entre los integrantes de la actividad al aire libre. Se recomienda realizar más investigaciones empíricas para comparar poblaciones que no participan en ninguna de estas actividades y también correlacionar sus puntajes para determinar si las actividades al aire libre generan conciencia sobre los problemas ambientales y si son utilizadas como herramienta en la educación ambiental en Paraguay.*

Palabrasclave: escala NEP, comportamiento ecológico, exploración socioambiental, estudio psicométrico, conducta ambiental, conciencia ambiental.

I. INTRODUCCIÓN

Los problemas ambientales son una preocupación mundial. En América Latina y el Caribe se perdieron 138 millones de hectáreas de bosques entre el año 1990 y el 2020 según la Comisión Económica para América Latina y el Caribe (CEPAL, 2021, p. 2) mientras que a nivel local en Paraguay el bosque Atlántico del Alto Paraná disminuyó en 46,6% y 24,8% desde las décadas de los 80 y los 90 respectivamente (WEHRLE, 2018). Del mismo modo los análisis de imágenes satelitales muestran que el Chaco paraguayo viene perdiendo su cobertura boscosa a tal ritmo que se puede concluir que de mantenerse habrá un cambio inaplazable en la matriz del paisaje para el año 2032 cuando la superficie de uso pecuario superará a la superficie de cobertura boscosa (GARCÍA-CALABRESE et al., 2017).

A este contexto se suma el hecho de que, políticamente, existen pocos esfuerzos para proteger los recursos naturales en el Paraguay. Al contrario, las leyes y reglamentaciones se vuelven cada vez más flexibles para explotar la biodiversidad sin que el país tenga la capacidad logística de controlar estas reglamentaciones. Un ejemplo es la Ley Forestal 422/73 que obliga a los productores a preservar 25% de la superficie boscosa natural. Esta ley fue reglamentada por el decreto 7702 firmado en el año 2017 y el cual daba un marco de legalidad para deforestar las reservas de bosques de estas propiedades, según menciona en su portal la WWF Paraguay (2017). Este decreto fue derogado en el siguiente gobierno con el decreto 175/18, pero para ese momento miles de hectáreas ya habían sido perdidas sin mayores consecuencias para los productores según declaraciones de las mismas autoridades (RDN, 2017).

Otro ejemplo reciente es la Resolución número 38 aprobada en enero del 2024 por la cual se aprueba el plan nacional de cacería deportiva en el Paraguay enmarcado dentro de la Ley 96/92 de vida silvestre. Esta resolución también flexibiliza la cacería de fauna silvestre estableciendo límites que podrían ser muy difíciles de controlar para las autoridades y de comprender por parte del público por falta de recursos y de conocimiento. Esto se da porque en muchos casos los ambientes y especies vulnerables a estas actividades son poco estudiados a nivel local.

De esta manera, la conservación ambiental en general en el Paraguay queda mayormente en manos de la conciencia ambiental de la población reconociéndose así la importancia de los actores sociales y sus actitudes hacia el ambiente y el uso sustentable de los recursos naturales. De hecho, se reconoce en varios estudios que la participación social es la estrategia más importante para lograr la preservación de los bosques y la biodiversidad (YU IWAMA & DELGADO, 2018;), pero a pesar del reconocimiento generalizado del rol del ser humano en la pérdida de estos recursos, la vasta mayoría de las investigaciones locales se enfocan en la dimensión ecológica y muy poco en la dimensión humana, los comportamientos pro ambientales (CPA) y sus aspectos subyacentes como lo es la preocupación personal o individual por el medio ambiente, también conocida como "conciencia ambiental" (CA) (VOZMEDIANO Y GUILLÉN, 2005).

Como estrategia para fomentar las CPA y aumentar la CA, las áreas naturales no solo mejoran el desempeño cognitivo, sino que contribuyen a la incorporación de conceptos directamente relacionados a la educación ambiental (MOCIOR & KRUSE, 2016). La educación ambiental formal e informal desde la escuela hasta la educación superior, son claves para contribuir a una visión más pro-ecológica en cada generación (DUNLAP & VAN LIERE, 2008). El contacto con la naturaleza a través de los deportes refuerza actitudes y valores ambientales como resultado de una educación informal.

Teniendo en cuenta el gran número de estudios empíricos sobre el efecto de los deportes y actividades físicas en ambientes naturales y al aire libre como parques y bosques en la CA (BERNS & SIMPSON, 2009; BJERKE et al., 2006; D'AMATO & KRASNY, 2011 DUNLAP & HEFFERMAN, 1975; GEISLER et al., 1977; THEODORI et al., 1998; RALPH BUCKLEY, 2006) y bajo el supuesto de que estas actividades contribuyen a un aumento en ella, este estudio busca comprender la estructura de la conciencia ambiental como un componente del comportamiento proambiental de una población que tiene un contacto directo con estos ambientes.

1.1 Escala NEP: Antecedentes

La preocupación con los problemas ambientales empezó a ganar destaque en los años 70 y 80 con desastres ambientales como el de Chernóbil, también en los 70 se dió inicio a los grandes debates sobre la problemática ambiental. Estos se extendieron a través de los años 80 y los 90 en la conferencia de las Naciones Unidas para el medio ambiente de Río 92 de la cual se redactó el informe de Brundtland dónde se definió el desarrollo sustentable como el que atiende a las necesidades del presente sin comprometer las necesidades del futuro (BELLIA, 1996)

El punto de quiebre sobre las cuestiones ambientales fue tal en estos años que se crearon los primeros partidos políticos verdes re-afirmándose algunas ideas de conservación de la Naturaleza que remontaban al siglo XIX por ejemplo al declararse patrimonio de la humanidad al parque Yellowstone, una de las primeras áreas silvestres protegidas de EE.UU. que fue creada en 1872 (FLOCHI, 2019).

La psicología ambiental tuvo sus orígenes bajo el término psicología ecológica a principios del siglo XX pero no fue hasta los años 70 que se dió el verdadero nacimiento de esta disciplina y se constituyó progresivamente en el contexto de los problemas sociales y ambientales de ese momento (MOSER, 2014).

En 1978, Dunlap y Van Liere propusieron un instrumento que analiza el sistema de creencias sobre los nuevos paradigmas ecológicos (NEP scale) siendo esta una escala capaz de medir con fiabilidad las creencias sobre la relación de los seres humanos con el planeta (GOMERA et al., 2013). La escala fue publicada en *The Journal of Environmental Education* por Riley E. Dunlap and K. D. Van Liere en 1978 y desde entonces se convirtió en el método más utilizado para medir la CA en el mundo y se ha aplicado en cientos de investigaciones que exploran las diferencias en el grado de CA en la población (DUNLAP & VAN LIERE, 2008).

Las revisiones de este instrumento a su vez han sido constantes desde el primer momento, tanto para adaptar la escala a los diferentes contextos como para optimizar su funcionalidad (LALONDE & JACKSON, 2002).

La escala tiene gran utilidad para encontrar puntajes en poblaciones que tendrán poder de decisión sobre los recursos y que tomarán decisiones en el campo por ejemplo de los agronegocios que deberán ser consistentes con la sustentabilidad y la protección del ambiente (KARAPANDŽIN & RODIĆ, 2017)

1.2 Actividades de contacto con áreas naturales

Los participantes de actividades recreativas al aire libre son vistos como colaboradores para las áreas naturales donde realizan sus actividades. Por esta razón se observa un creciente número de investigaciones sobre las motivaciones del público a participar de estas actividades como un gran aporte para mejorar la sustentabilidad de los programas de recreación y conservación de áreas naturales (MILLER et al., 2020).

El mismo creador de la escala NEP, Riley Dunlap, midió la CA de participantes de actividades al aire libre clasificando estas actividades en contacto con la naturaleza en actividades de apreciación (caminatas, camping y visitas a parques) y de consumo (pesca, cacería) encontrando diferencias significativas entre los puntajes obtenidos para ambos grupos (DUNLAP & HEFFERMAN, 1975). Sin embargo, en los años 80 Van Liere (1981) probó sólo una leve relación entre estas actividades y CPAs posiblemente porque se evalúan grupos que de por sí tienen tendencia a elegir actividades en espacios naturales (VON LIERE & NOE, 1981).

Otros estudios revelan que programas que insertan a los participantes a un contacto directo con la naturaleza en sus estados más naturales revelaron sentir una transformación personal que la conectan con el deseo de querer hacer algo para proteger la naturaleza (D'AMATO & KRASNY, 2011). Además, los mismos participantes de este estudio revelaron haber elevado sus estándares de comportamiento medioambiental luego de haber participado en estos programas.

Las actividades con jóvenes en ambientes prístinos desarrollan en ellos un nuevo sentido de conexión con la naturaleza y una preocupación positiva hacia el mundo natural (HALUZA-DELAY, 2001).

El solo hecho de vivir cerca de áreas naturales, en muchos casos puede constituir un factor que afecta positivamente la CA. En Nigeria en el año 2012 se encontró que una gran mayoría mantiene una percepción de dominio del ser humano sobre la naturaleza a pesar de demostrar actitudes positivas hacia la conciencia de límite y de equilibrio con la naturaleza medidas a través de la escala NEP (OGUNJINMI et al., 2012).

II. MÉTODOS

El trabajo se basó en análisis correlacionales y de distribución de medias de datos obtenidos a través cuestionarios de Google Forms enviados a través del link a un público seleccionado de manera directa. Se calculó el tamaño de la muestra representativa con el programa EpiInfo versión 7.2.4.0 usando 95% de confianza, 5% de margen de error aceptable.

Teniendo en cuenta que la percepción del valor económico de los recursos naturales tiene cierta influencia, que no se puede medir en este trabajo, pero que se puede presumir afecta directamente a las respuestas obtenidas (REIS CAMPOS et al. 2005) se mantuvieron las características socioeconómicas lo más homogéneas posible para que este no sea un factor qué afecte a los puntajes obtenidos.

Se utilizó la versión de 14 ítems adaptada y validada por Bóveda y Delgado (2022) de la escala NEP propuesta originalmente por Dunlap y Van Liere (1978) y extraída de la versión en español de Gomera (2013). Este instrumento utilizó una escala de puntuación Likert de 5 puntos

Se realizaron las pruebas de fiabilidad de Alfa Cronbach, Kaiser-Meyer-Olkin (KMO) de adecuación de muestreo y de esfericidad de Barlett, análisis factorial exploratorio (AFE) de la escala para establecer la estructura interna del instrumento a través de los factores a ser analizadas. Para maximizar la carga de los factores se aplicó la rotación ortogonal Varimax, análisis de los componentes principales para determinar las dimensiones descritas por estos factores y se les otorgó los nombres correspondientes a cada factor, tabla de distribución de frecuencias para identificar tendencias de percepción de los participantes hacia el ambiente, prueba de Normalidad para 3 grupos clasificados de la siguiente manera:

- M1: Actividades deportivas de pocas horas dentro de las áreas urbanas de Paraguay o "de ambientes urbanos" ambientes urbanos de menor contacto con la naturaleza, dentro de gimnasios, de áreas con alto grado de construcción y poco espacio verde.
- M2: Actividades deportivas en parques dentro o cercanos a Asunción o "de ambientes semiurbanos" qué incluye parques naturales cercanos o dentro de las ciudades como el jardín botánico, las costaneras y otras áreas verdes.
- M3: Actividades deportivas de más de un día en áreas naturales de Paraguay distantes de Asunción a más de 100 km o "de ambientes de áreas naturales" ya sea en reservas, parques, bosques, ríos, lagunas y otros paisajes a través de un esfuerzo físico intenso y duradero permite a los practicantes un contacto y una experiencia todavía más profunda dentro de estas áreas.

Se analizó la diferencia de medias con la prueba H de Kruskal-Wallis para diferencias de medias en función a los componentes obtenidos para escala NEP en función al grado de contacto con las áreas naturales.

Finalmente se analizaron los resultados para evaluar si los puntajes obtenidos en las dimensiones intrínsecas del test reflejan una conciencia ambiental elevada determinando así si constituyen estas actividades constituyen un servicio de las mismas a través de la concienciación hacia el medio ambiente.

III. RESULTADOS Y ANÁLISIS

3.1 Participantes

Según el formulario introductorio al test enviado a la población de practicantes de actividades deportivas al aire libre, la muestra resultó estar compuesta de la siguiente manera:

• Rango edad: 18-50 años (edad media 21.6 años).

• Sexo: % hombres y % mujeres.

• Perfil académico: Universitario 86.3%; Técnico 9.8%; Secundario 3.9%

Las actividades económicas de profesional asalariado (privados y públicos) y empresarios (unipersonales o sociedades) juntas componen más del 75% de las respuestas.

La estructura etaria es de 8.9% entre 18 y 25 años, 34.6% entre 26 y 35 años y 55.9% tienen más de 35 años.

3.2 Validación del test

El total de respuestas obtenidas a través de Google Forms fueron exportadas directamente a una planilla de datos la cual fue cargada al programa SPSS. Se obtuvo un valor aceptable alfa Cronbach

0.739 para los 14 ítems analizados de la escala. Se realizó la prueba de KMO y Barlett obteniéndose 0.852 y 1500.11 respectivamente, ambos valores permiten realizar el análisis factorial.

3.3 Componentes Principales

Mediante el análisis factorial o Análisis de Componentes Principales (PCA) se explica más del 55% de la varianza de la CA. Teniendo una reducción de datos mediante análisis factorial de extracción y de rotación Varimax se obtienen 3 factores principales nombrados Ecocentrismo, Conciencia de Límite de Recursos y Antropocentrismo Ambiental. En el gráfico de sedimentación se identifican los tres autovalores superiores (Figura 1).

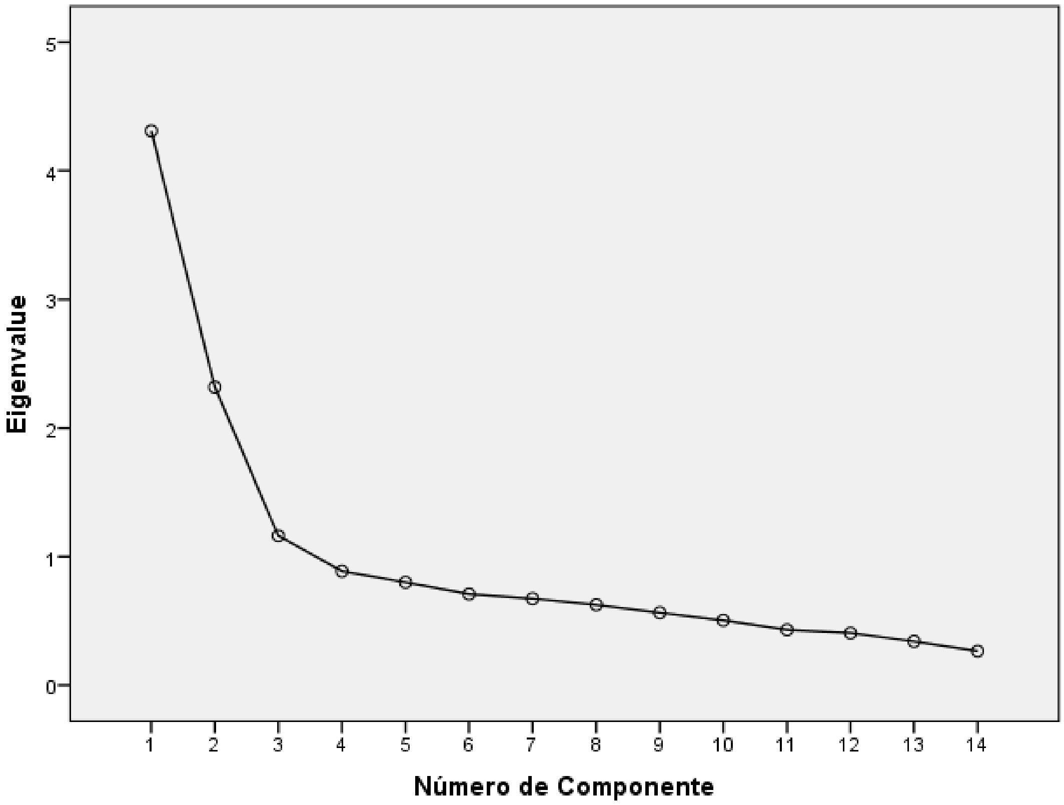

Figura 1: Gráfico de sedimentación de autovalores correspondiente a cada componente.

Las cargas factoriales finales luego de la aplicación de la rotación Varimax ubicaron a 7 ítems (9, 8, 4, 15, 11, 13, 3 de mayor a menor) dentro del factor 1; 4 ítems (12, 10, 16, 7 de mayor a menor) dentro del factor 2; 3 ítems (6, 5, 2 de mayor a menor) dentro del factor 3 (Tabla 1).

Tabla 1: Matriz de Componentes Rotados

	Componentes		
	1	2	3
Item9	.805	-.010	-.011
Item15	.793	.024	-.058
Item8	.788	-.057	.036
Item4	.787	.064	.027
Item11	.779	.006	-.156

Item13	.716	.024	.102
Item3	.698	.060	.068
Item12	-.007	.723	.036
Item10	-.088	.720	.063
Item16	.050	.701	.065
Item7	.128	.643	.168
Item6	-.035	.182	.776
Item5	-.119	.258	.693
Item2	.375	-.195	.472
Método de Extracción: Análisis de Componentes Principales Método de Rotación: Varimax con normalización Kaiser			
a. Rotation convergente en 5 iteraciones.			

3.4 Análisis teórico de los componentes principales

Mediante la aplicación de la escala NEP en diferentes estudios el análisis factorial confirmatorio de los resultados arrojan desde 1 hasta 6 factores o dimensiones internas. Al comparar los diferentes factores y ser analizados según su contenido los componentes principales se clasificaron de la siguiente manera:

Factor 1: *Ecocentrismo:* Corresponde a los ítems 9, 8, 4, 15, 11, 13, 3 que incluye afirmaciones que reflejan preocupación y respeto hacia la naturaleza y el medio.

Ítem 9. El equilibrio de la naturaleza es muy delicado y fácilmente alterable por las acciones humanas.
Ítem 8. Si seguimos modificando el medio ambiente como hicimos hasta ahora, pronto experimentaremos una gran catástrofe ecológica.
Ítem 4. Las plantas y los animales tienen tanto derecho como los seres humanos a existir y sus ambientes deben ser respetados.
Ítem 15. Cuando los seres humanos alteran un ambiente natural, muchas veces las consecuencias son desastrosas para la naturaleza y las personas de ese lugar.
Ítem 11. Como humanidad, estamos abusando de nuestra capacidad de explotar los recursos naturales.
Ítem 13. Para lograr un desarrollo sostenible para los seres humanos y el medio ambiente necesitamos controlar el crecimiento industrial y la producción a gran escala.
Ítem 3. Los seres humanos estamos sujetos a las leyes de la naturaleza así como todos los otros seres vivos del planeta.

Factor 2: *Conciencia límite de los recursos:* Incluye los ítems 12, 10, 16, 7 que reafirman la noción de que los recursos naturales pueden ser aprovechados sin límites y sin que eso represente una amenaza para la humanidad. Esta nominación difiere del estudio anterior con la población de deportistas del Paraguay de BÓVEDA & DELGADO (2022).

Ítem 12. El equilibrio de la naturaleza es lo bastante fuerte para recuperarse del impacto que los países industrializados y productores le causan.
Ítem 10. La idea de que la humanidad va a enfrentarse a una crisis ecológica global es una idea exagerada, todo está bajo control.
Ítem 16. La naturaleza existe para que sea aprovechada y utilizada por los seres humanos, esa es su finalidad.
Ítem 7. La tierra tiene recursos naturales en abundancia y vamos a aprender la manera correcta de explotarlos para que sean inagotables.

Factor 3: ***Antropocentrismo ambientalista:*** Agrupa a los ítems 6, 5, 2 que incluyen afirmaciones sobre el ser humano y la importancia de asegurar la supervivencia de la humanidad sin limitar el uso de los recursos por la población humana que habita la tierra, pero limitando el tamaño de la población humana para que se puedan seguir utilizando los recursos de manera segura. Además, este factor agrupa 3 ítems que hacen referencia nula hacía la naturaleza como protagonista, sino que pone al ser humano en primer plano. La denominación de este grupo es nueva y difiere del anterior estudio con la población de deportistas del Paraguay de BÓVEDA & DELGADO (2022) buscando reflejar el interés del ser humano hacia la naturaleza, pero para su propio beneficio y sin que eso implique una preocupación por la naturaleza.

Ítem 6. Con seguridad los seres humanos van a desarrollar tecnologías para ser capaces de controlar a la naturaleza por completo.
Ítem 5. Los seres humanos tienen derecho a intervenir en los paisajes naturales y el medio ambiente incluso para obtener beneficios que no son esenciales para subsistir.
Ítem 2. Actualmente ya llegamos al número límite de personas que el planeta Tierra puede albergar.

3.5 Comparación de grupos

Al comparar los puntajes obtenidos en función a los diferentes grados de contacto con la naturaleza que implican las actividades deportivas de la población estudiada a través de una prueba de normalidad para los tres grupos con una probabilidad de error de 5% y los tres factores resultantes del análisis factorial. Analizadas por separado, se utilizaron los valores de la prueba de Kolmogorov-Smirnov para los grupos de M3 y M1 que corresponden a muestras mayores a n=50 mientras para el grupo de M2 se utilizan los valores de la prueba de Shapiro-Wilk para muestras <50. No se encuentran diferencias significativas en ninguno de los factores según el ambiente en sus diferentes grados de contacto con la naturaleza M1, M2 y M3 (Tabla 2).

Tabla 2: Kruskal-Wallis para los factores según todos los Ambientes

	Ecocentrismo	Conciencia de Límite de los recursos	Antropocentrismo Ambientalista
Chi-Square	2.456	.185	.697
df	2	2	2
Asymp. Sig.	.293	.912	.706
a. Kruskal Wallis Test	b. Grouping Variable: Tipo de ambiente		

Habiendo obtenido estos resultados, se combinaron los tres grupos de maneras alternativas para explorar la posibilidad de que la población corresponda a dos tipos de ambientes donde el intermedio no se diferencia significativamente de uno de los ambientes extremos. Para eso se combinó la muestra de ambientes semiurbanos con la muestra de los ambientes naturales y urbanos en dos análisis separados.

3.5.1. Semi urbano como ambiente natural

Al ser el ambiente semiurbano un entorno que incluye componentes tanto naturales como urbanizados, se hizo la prueba de considerarlo como ambiente natural para corroborar que efectivamente no sean 3 grupos sin diferencias significativas pero son dos grandes grupos que presentan diferencias en sus puntajes para el instrumento. Para esta comparación se utilizó la prueba de U Mann-Whitney, en la que no se obtuvo ninguna diferencia significativa (Tabla 3). Esta configuración alternativa resultó en 2 grupos sin diferencias significativas.

Tabla 3: U de Mann-Whitney para los factores según M1 y M2+M3

	Ecocentrismo	Conciencia de Límite de los recursos	Antropocentrismo Ambientalista
Mann-Whitney U	8982.500	9910.000	9815.500
Z	-1.555	-.358	-.482
Asymp. Sig. (2-tailed)	.120	.720	.630
a. Grouping Variable: Ambiente Urbano o Semiurbano/Natural			

3.5.2. Semi urbano como ambiente urbano

Del mismo modo, al ser el ambiente semiurbano un entorno que incluye componentes tanto naturales como urbanizados, se hizo la prueba de considerarlo como ambiente urbano el cual quizás no conlleva un contacto intenso con la naturaleza que implique un mayor efecto en la CA. Para esta comparación se utilizó la prueba de U Mann-Whitney, en la que tampoco se obtuvo ninguna diferencia significativa (Tabla 4). Con esta prueba se corrobora que el grupo de deportistas de los diferentes ambientes analizados constituyen un grupo homogéneo para la CA medida a través de la escala NEP.

Tabla 4: U de Mann-Whitney para los factores según M1+M2 y M3

	Ecocentrismo	Conciencia de Límite de los recursos	Antropocentrismo Ambientalista
Mann-Whitney U	13831.500	14279.500	13898.500
Z	-.899	-.417	-.829
Asymp. Sig. (2-colas)	.368	.677	.407
a. Variable de agrupación: Ambiente Urbano/Semi urbano o Natural			

3.6 Estadísticos descriptivos

Al analizar los puntajes del grupo completo en función a los componentes principales para esta escala se obtuvieron los valores más altos para el factor Ecocentrismo siendo la media mayor a 30 (el puntaje máximo es 35) mientras que la media para el factor Conciencia de Límite de los Recursos se obtuvo un valor medio de 9.83 (su valor máximo es 20) y de manera similar para el factor Antropocentrismo Ambiental el puntaje medio obtenido es de 7.28 puntos (de un máximo de 15).

Tabla 5: Estadísticos descriptivos

	Ecocentrismo	Conciencia de Límite de los recursos	Antropocentrismo Ambiental
N	362	362	362
Media	30.12	9.83	7.28
Desv. Std.	5.719	3.822	2.423
Mínimo	7	4	3
Máximo	35	20	15

El factor "Ecocentrismo" acumuló un puntaje alto, la mayoría de las respuestas dan un peso máximo o cercano al máximo a las afirmaciones que refieren a la naturaleza como una prioridad y a los problemas ambientales como una preocupación (Figura 2).

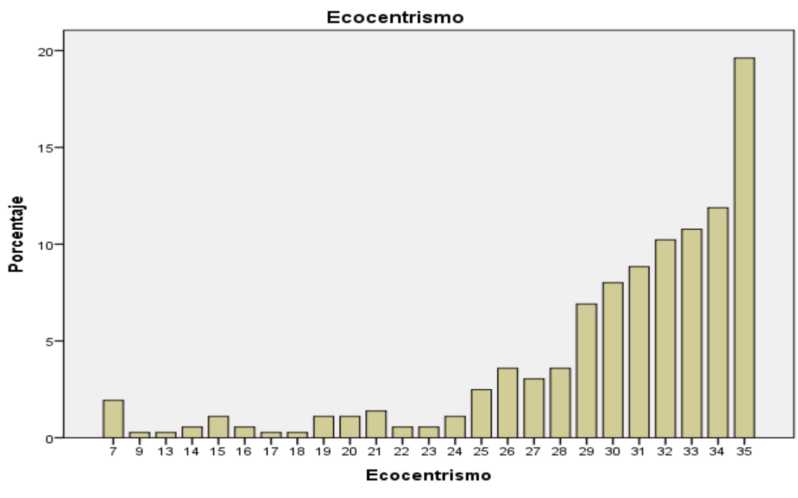

Figura 2: Gráfico de porcentaje de puntajes para Ecocentrismo

El factor “Conciencia de límite de los recursos” ha acumulado un puntaje con una tendencia cercano a la mitad del puntaje total para las afirmaciones que refieren a los recursos naturales como inagotables o manejables (Figura 3). Aunque la tendencia de estos puntajes es moderadamente baja, no deja de reflejar que esta población tiende a creer que los recursos están amenazados.

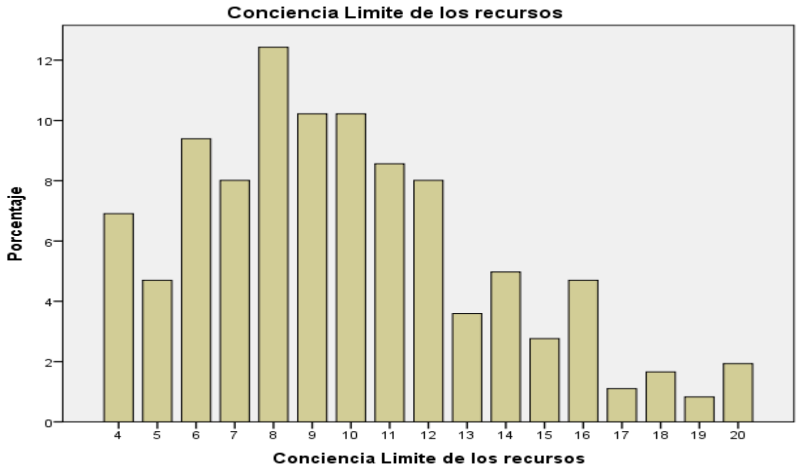

Figura 3: Gráfico de porcentaje de puntajes para Conciencia de límite de los recursos

Para la dimensión del Antropocentrismo Ambientalista, los puntajes siguen una tendencia similar a la anterior donde las afirmaciones refieren al ser humano y sus intereses como preocupación principal, estos ítems reflejan preocupación con la naturaleza como recurso para la supervivencia del ser humano. Los puntajes son bajos para esta dimensión sin embargo la tendencia no es tan marcada como en el caso del Ecocentrismo (Tabla 4).

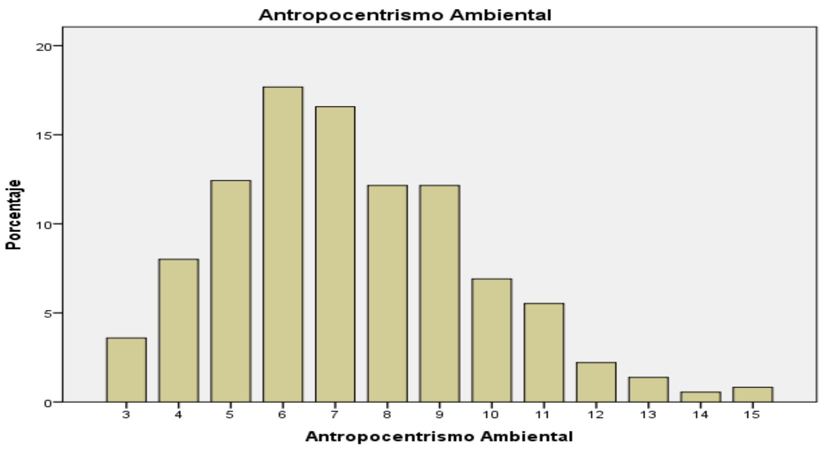

Figura 4: Gráfico de porcentaje de puntajes para Antropocentrismo Ambientalista

3.7 Correlaciones

Se obtuvo una correlación significativa (sig. 0.000), con un nivel del 1%, entre las variables Antropocentrismo Ambiental con la variable Conciencia del Límite de los Recursos (Tabla 6). Se observa una relación positiva débil (r=0.219), en la que se entiende que a un mayor nivel de Conciencia del Límite de los Recursos se relaciona un mayor nivel de Antropocentrismo Ambiental.

Tabla 6: Correlación de Spearman entre componentes

			Ecocentrismo	Conciencia de Límite de los recursos	Antropocentrismo Ambiental
Rho de Spearman	Ecocentrismo	Coef. de Correl.	1.000	-.070	.071
		Sig. (2-colas)	.	.185	.178
		N	362	362	362
	Conciencia Límite de los recursos	Coef. de Correl.	-.070	1.000	.219**
		Sig. (2-colas)	.185	.	.000
		N	362	362	362
	Antropocentrismo Ambiental	Coef. de Correl.	.071	.219**	1.000
		Sig. (2-colas)	.178	.000	.
		N	362	362	362
**. La correlación es significativa al nivel de 0,01 (de 2-colas).					

IV. DISCUSIÓN

4.1 Variables no paramétricas

Los análisis de normalidad y de la distribución de los puntajes de los factores resultantes de los componentes principales, muestran que las distribuciones de las mismas no siguen los patrones de normalidad y homogeneidad de medias y varianzas respectivamente.

Esto puede tener varias explicaciones intrínsecas a cada individuo y a nivel poblacional como ser que las percepciones relacionadas a las creencias sobre el medio ambiente y los recursos naturales pueden estar muy relacionadas a razones económicas, familiares, culturales, religiosas y en nuestra población resulta muy difícil desprenderse de ciertos hábitos para adoptar otros más ecológicos. En este sentido, el promedio de respuestas podría ser aleatorio desviándose poco o mucho de la tendencia central según cuestiones personales como las citadas anteriormente.

Además, el contacto con la naturaleza a través de los deportes revela una realidad en la cual los participantes ven con sus propios ojos la pérdida de los bosques y otros recursos al pasar por ellos en un momento y luego volver a pasar tiempo después y notar el cambio en detrimento del medio ambiente y en beneficio de los intereses personales y de la economía. Estas personas probablemente se alejarán de la media de respuestas según puedan aceptar esa realidad o no.

No es menos importante tener en cuenta que es sabido que el deporte en general, a través de la producción de serotonina y otros resultados directos del ejercicio, dan a los seres humanos cierto placer y sensación de bienestar (DURÁN GONZÁLEZ et al., 2017), mientras que se ha estudiado la relación que tiene la felicidad y la adherencia a los nuevos paradigmas ecológicos medidos a través de la escala NEP donde se encontró que las creencias generales acerca del ambiente aparecen asociadas a la felicidad (MOYANO-DÍAZ et al., 2011).

Los factores individuales resultan igualmente importantes para determinar la preocupación por el ambiente como muestran los resultados de estudios similares ya en los años 70, siendo los cambios económicos en el tiempo igualmente importantes para la formación de este constructo según el mismo estudio (GEISLER et al., 1977).

4.2 Puntajes

Los puntajes obtenidos reflejan un alto grado de conciencia ambiental al tener en cuenta que los dos factores antropocentristas obtuvieron valores más bajos en comparación al factor ecocentrista que obtuvo un puntaje alto.

Al analizar el alto puntaje obtenido para el factor ecocéntrico y los puntajes moderadamente bajos para los dos factores antropocéntricos se puede analizar la estructura etaria de la muestra, la misma está compuesta por personas mayormente sobre los 35 años lo cual podría reflejar creencias adquiridas en la infancia/juventud cuando el mundo manejaba conceptos claramente volcados al ser humano como centro.

Otro factor a tener en cuenta que podría aclarar esta homogeneidad de la población en términos de conciencia ambiental medidos por la escala NEP, es el nivel de educación de los participantes que resultaron ser mayormente universitarios. En aplicaciones de la escala NEP se ha demostrado que el conocimiento sobre cuestiones ambientales como los ecosistemas contribuye fuertemente a endosar los NEP (PUTRAWAN, 2015; HARRAWAY et al., 2012). Según Gomera Martínez et al. (2012), independiente a la carrera, los grados universitarios incluyen conocimientos ambientales, es posible que las muestras tengan conocimientos básicos suficientes para comprender la problemática de manera similar.

Las correlaciones encontradas refuerzan esta tendencia siendo los factores antropocéntricos correlacionados entre sí mientras que el factor ecocéntrico es opuesto ambos.

V. CONCLUSIONES Y RECOMENDACIONES

Las creencias de la población de deportistas estudiada se caracteriza por un alto grado de CA ambiental, esto no debe perder de vista que ser conscientes de los problemas que afronta el planeta en términos de conservación de recursos naturales no necesariamente se traduce en comportamientos que protejan estos recursos (MEJÏA, 2020), sobre todo teniendo en cuenta que los dos factores antropocéntricos tuvieron puntajes moderadamente bajos.

Los ítems de la escala NEP reflejan distintas dimensiones internas que juntas, y según la distribución de sus puntajes, describen en cierta medida la manera de ver la problemática ambiental. En este estudio, el factor 3 agrupa tres ítems que pueden ser analizados en mayor profundidad en evaluaciones posteriores que se enfoquen en comprender una visión de mayor preocupación por la supervivencia de la humanidad, donde vemos al ser humano como capaz de manejar una situación que es por cierto preocupante o amenazante. Para comprender mejor esta dimensión en futuras exploraciones deben ser revisadas las palabras y adaptadas las afirmaciones de acuerdo al contexto de la población estudiada (FREIRE et al., 2021).

El alto puntaje obtenido en la dimensión de Ecocentrismo es un indicio importante de que el deporte al aire libre contribuye a la conexión con el entorno, la naturaleza y los recursos naturales y que los ítems originales de este instrumento representan en muchos casos cuestiones ya resueltas por la población en general de deportistas con las características sociodemográficas descritas y, por esta razón, se puede hablar de un incremento en la CA medida a través de la escala de los nuevos paradigmas ecológicos asumiendo que en tiempos anteriores Paraguay seguía la tendencia global para estos valores en donde estas variables eran mayormente cuestionadas por la población.

En resumen, el análisis univariado de las varianzas de los puntajes finales obtenidos demostró un alto grado de conciencia ambiental en la población estudiada mientras que el análisis multivariado de las varianzas no mostró correlación con grados de contacto con la naturaleza a través de los deportes al aire libre como factores que afectan la CA.

Teniendo en cuenta la importancia y utilidad de hacer esfuerzos conjuntos para validar instrumentos de medición de alta calidad sobre las preocupaciones ambientales que sean comparables a nivel internacional (WANG & SUN, 2021) se recomienda explorar variaciones y adaptaciones de los ítems de este instrumento a nivel local con el fin de cubrir los paradigmas ambientales específicos en cada caso sin perder de vista los constructos mayormente explorados a nivel mundial.

Además, aunque estudios recientes siguen validando la escala NEP y demostrando que es útil para realizar monitoreos de la conciencia ambiental (GOTTSCHE et al, 2024) se propone realizar el mismo estudio utilizando otras escalas que revelan factores o dimensiones internas alternativas como la "Escala teoría cultural de cosmovisiones ambientales" han sido validadas en español y que permiten hacer mediciones psicoambientales y comparaciones a nivel regional profundizando en los componentes socioculturales de los CPAs (SANDOVAL DÍAZ et al., 2020).

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Analysis of Novel Nanocatalyst to Enhance Fame Volume

S .Kaleeswaran, H. Gayathri, N. Pagalavan, V. Nagarjun, A. P. Ramanidharan, P. Sathish & T. Nandhini

ABSTRACT

Fossil fuels are produced by non-renewable sources. The non-renewability is motivated for alternative fuels. Some common examples of feedstock for alternative fuels are seed oil, vegetable oil, waste cooking, soybean oil. Biodiesel is produced through transesterification reaction. Biodiesel production from waste cooking oil provides an alternate energy for various uses. Recycling waste cooking oil and methanol with the presence of (CaO) and (MgO) nano catalysts offers several benefits like economic, environmental and waste management. The nano catalysts CaO and MgO was synthesized by thermal decomposition method and calcinated at 500°C followed by characterization using diffraction (XRD) technique and RSM (Response Surface Methodology) is performed for optimization of the yield. This study investigates the repeatability of transesterification reaction with the presence of those nano catalysts.

Keywords: renewable fuel, nano catalyst, waste cooking oil, transesterification reaction.

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ABSTRACT

Fossil fuels are produced by non-renewable sources. The non-renewability is motivated for alternative fuels. Some common examples of feedstock for alternative fuels are seed oil, vegetable oil, waste cooking, soybean oil. Biodiesel is produced through transesterification reaction. Biodiesel production from waste cooking oil provides an alternate energy for various uses. Recycling waste cooking oil and methanol with the presence of (CaO) and (MgO) nano catalysts offers several benefits like economic, environmental and waste management. The nano catalysts CaO and MgO was synthesized by thermal decomposition method and calcinated at 500°C followed by characterization using diffraction (XRD) technique and RSM (Response Surface Methodology) is performed for optimization of the yield. This study investigates the repeatability of transesterification reaction with the presence of those nano catalysts.

Keywords : renewable fuel, nano catalyst, waste cooking oil, transesterification reaction.

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I. INTRODUCTION

Fuel plays a crucial role in powering vehicles and industries, with fossil fuels being the primary source. However, the lengthy formation process spanning millions of years and limited availability underscore the need for alternative fuel sources. Biofuels emerge as a viable substitute, derived from living organisms and produced through shorter, biological processes. This renewable energy source, including bioethanol and biodiesel, offers distinct advantages.

Bioethanol, a liquid fuel, is obtained through biological processes employing microorganisms and enzymes. Sugarcane and wheat serve as sources, with fermentation and distillation separating bioethanol from other components. It can be used as an additive with gasoline, reducing carbon monoxide emissions. Biodiesel, produced via transesterification using vegetable oil and fat, features resources like soybean oil and waste cooking oil. It proves effective in fuel mixtures, lowering unfavorable gas emissions by up to 60%.

While burning biofuels contributes to air pollution, the impact is comparatively lower than that of fossil fuels. The benefits of biofuels encompass lower emissions, renewability, biodegradability, and safety. They produce fewer greenhouse gases and are easily obtained from organic materials, making biofuels a sustainable energy source derived from readily available resources like plant biomass.

II. MATERIALS AND METHODS

2.1 List of Samples

Waste cooking oil (WCO)

2.2 List of Chemicals

Methanol, NaOH, Calcium nitrate Ca(NO3)2, Magnesium nitrate Mg(NO3)2, Ethylene glycol

2.3 List of instruments

Magnetic stirrer, Water bath, XRD (X-ray Diffraction), Muffle furnance.

2.4 Waste Cooking Oil sample preparation (WCO):

Waste cooking oil was collected from local hotels, which has been used for food frying. The waste cooking oil was settled for 4-6 days at room temperature and later it was filtered to remove any suspended food particles and by heating at 60°C for water removal.

2.5 Nano-catalyst synthesis

MgO Nano catalyst was prepared by thermal decomposition method, it is a method that chemical decomposition of substance into constituents by heating. A solid material is heated beyond its decomposition temperature. CaO Nano catalyst was prepared by sol gel method. This method is a wet chemical technique that uses chemical solution to produce an integrated network(gel).

2.6 Catalyst characterization

The synthesized catalysts properties were characterized by X-ray diffraction (XRD) for identification of major components and for the determination of crystallite size.

2.7 Biodiesel Preparation

90ml of methanol poured into 250ml conical flask. The Sodium hydroxide 4g added with methanol solution. The mixture was shaken for 1 hour until catalyst fully dissolved in methanol. This is known as alkoxides sample. The alkoxides sample was added methanol 90ml and oil sample 90ml 1:1 ratio at 60°C, beyond this heat level it will leads to coagulation of oil sample. The transesterification reaction started at this movement. The reaction mixture was kept for 2 hours in shaker. After this sample was kept for layer separation by separator funnel. This experiment was also done in waste cooking oil using two types of catalysts Nano CaO and Nano MgO, in different ratio.

2.8 Nano CaO preparation

10 gram Ca(NO3)2 was dissolved in 25ml of ethylene glycol mixed by magnetic stirrer. 2 gram NaOH dissolved in 25ml distilled water added to the solution in the magnetic stirrer. Keep the solution in magnetic stirrer for 2 hours so that a clear white gel was obtained. The white gel was left over for extra 2 hours at room temperature for the reaction to complete. Then after 4 times of being washed with water, NaOH was excreted. After that the gel was heated up to 80°C for 2 hours so that the water content could be vapourized and the gel concentrated. The resulting dry gel was milled in the form of white powder. The produced 12g powder was put in the cruse and into the oven which was gradually heated up to 500°C for 2 hour for decarbonization.

2.9 Nano MgO preparation

1.5 gram Mg(NO3)2 was dissolved in 50ml distilled water, mixed by magnetic stirrer. 0.5 gram NaOH was dissolved in 25ml distilled water, added to the solution in the magnetic stirrer. Keep the solution in magnetic stirrer for 2 hours so that a clear white gel was obtained. The white gel was left over for extra 2 hours at room temperature for the reaction to complete. Then after 4 times of being washed with water, NaOH was excreted. After that the gel was heated up to 80°C for 2 hours so that the water content could be vapourized and the gel concentrated. The resulting dry gel was milled in the form of white powder. The produced 5g powder was put in the cruse and into the oven which was gradually heated up to 500°C for 2 hour for decarbonization.

2.10 Preparation Of Sample

Waste Cooking Oil (used cooking oil) was Collected from restaurants and hotels. It is stored in a bottle and left over 3 day for settling down of impurities like food partices.

2.11 Process of reaction

100ml wco sample collected and filtered, heated upto 60°C meanwhile 1 gram nano catalyst (CaO) was dissolved in 20ml methanol, the dissolved catalyst solution is added to the heated wco which was placed under magnetic stirrer, keep in magnetic stirrer for 30minutes. After that sample was kept for layer separation by separator funnel. Top layer is considered as fatty acid methyl ester (biodiesel) in the conical flask and bottom layer is considered as glycerol in the beaker.

2.12 Transesterification steps

Take 100ml of Waste Cooking Oil sample. Preheat the sample at 50-60°C .Take 20ml of methanol and 1 gram of Nano CaO which was prepared earlier, mix it well in the conical flask.The sample is kept in magnetic stirrer at 50-60°C , the solution in the conical flask is added to the sample in magnetic stirrer. Maintain a speed of 890rpm and reaction is continued for above one and half an hour. After reaction time is completed, this mixture send to the separating funnel for glycerol settling down, the glycerol mixture in biodiesel settle in separating funnel with in 6- 12 hours. Remove the glycerol from the separating funnel and biodiesel is send to washing. The non polar methyl ester molecules making up the biodiesel do not mix with thempolar glycerol molecules and the mixture of products will separate into two layers with the less dense biodiesel floating on top of the more dense glycerol layer. The method of removing glycerol is mainly by gravity separation or centrifugation. In this process the layers are separated with the help of separating funnel which is known as gravity separation.

2.13 Washing and Drying

After biodiesel and glycerol are separated, trace amount of glycerine remain in the biodiesel. It is a process of washing biodiesel of its contaminants. These contaminants include trace amounts of methanol, soap, glycerin and catalysts. They are washed out with warm water. Dry washing is another most regularly used technology in the dynamics of biodiesel purification process. After the biodiesel is washed, it should be dried until it is crystal clear. This can be done by heated about 50 °C for few hours.

III. RESULTS AND DISCUSSION

3.1 Biodiesel

Biodiesel is the generic name for the family of diesel fuel alternatives produced by transesterification of oils from agricultural feed stock. Waste cooking oil themselves from triglycerides as shown in Fig 3.1.1, which are esters derived from long chain fatty acids and polyalcohol glycerol. Some of the fatty acids have unsaturated chains. Fatty acid methyl ester is also called as biodiesel.

Fig.3.1: Biodiesel produced from

WCO using combination of Nano CaO and Nano MgO

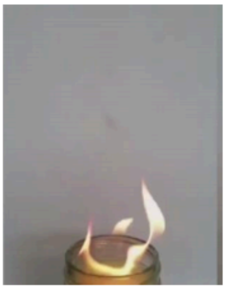

Fig 3.2: Flamming test for biodiesel obtained from WCO using combination of Nano CaO and Nano MgO

3.2 Analysis of Nanoparticles

The application of XRD showed that the crystal structure of the particles was cubic. Additionally, the comparison of the obtained peaks and source peaks indicated that the CaO NPs were synthesized and average particle size was calculated 61 nm according to Scherer's equation (Fig:3.2.1). Also, the comparison of the obtained peaks and source peaks indicated that the Mgo NPs were synthesized and average particle size was calculated 69 nm according to Scherer's equation ()

Scherer's equation:

$$D= {}^{k\lambda}/_{\beta_{hkl}} \cos\theta$$

D = crystallite size.

β

hkl = broadening of the hkl diffraction peak, measured at half of its maximum intensity.

Θ = Braggs angle.

k = shape factor.
λ = wavelength of radiation.

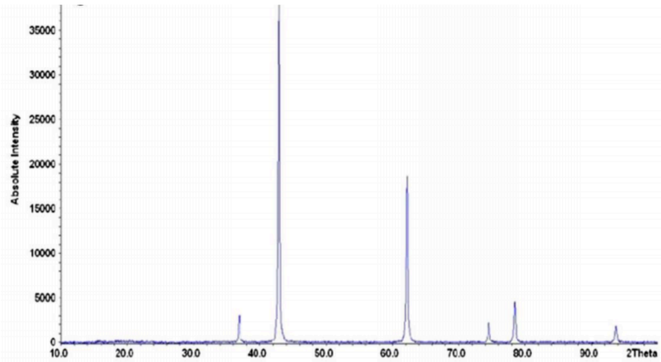

Fig.3.3: XRD analysis of presence of Nano CaO

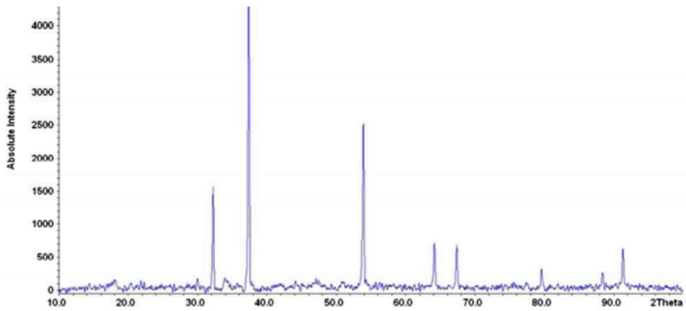

Fig.3.4: XRD analysis of presence of Nano MgO

3.3 Optimization of Reaction Conditions by RSM

Parametric effects such as temperature, reaction time, sample ratio, catalyst ratio and stirring speed are all important factors in the transesterification of waste cooking oil using Nano catalyst CaO and MgO. Their effect on waste cooking oil FAME yield was illustrated in Fig 3.3 to Fig 3.8 below.Experimental runs were carried out by a combination of the five variables resulting in a total 32 experimental runs best of 10 runs are presented in Table 3.1,Table 3.2 and Table 3.3.

Table 3.1: RSM Prediction using Nano CaO

RUN	Temperature (°C)	Reaction time (min)	Sample ratio (ml)	Catalyst ratio (g)	Stirring speed (rpm)	Output Yield %
1	60	67	80	2	590	72.63
2	50	45	100	8	400	75.34
3	60	35	90	5	590	69.67
4	65	67.5	100	5	590	72.59
5	70	45	75	2	400	54.87
6	60	67	75	5	590	65.12
7	70	45	100	2	780	67.85
8	50	90	70	2	780	55.32
9	70	90	80	8	780	64.27
10	70	90	90	8	400	78.58

3.4 Maximum yield using Nano CaO:

A maximum yield of 78.58% was obtained using optimum operating parameters of temperature 70°C, reaction time 90minutes, catalyst ratio 8g, sample ratio 90 ml and stirring speed 400 rpm.The effect of the different parameters on the actual yield RSM prediction is reported in table 3.2. It was observed that run 10 had the highest actual yield of 78.58% with reaction parameters, temperature 70 °C, reaction time 90minutes, catalyst ratio 8 g, sample ratio 90ml and stirring speed 400rpm.

Table 3.2: RSM Prediction using Nano MgO

RUN	Temperature (°C)	Reaction time (min)	Sample ratio (ml)	Catalyst ratio (g)	Stirring speed (rpm)	Yield %
1	55	60	85	2	590	78.58
2	50	45	100	3	400	64.27
3	60	50	75	5	590	55.32
4	65	65	75	5	590	67.85
5	70	45	75	2	400	54.87
6	60	65	75	5	590	65.12
7	65	45	100	2	780	72.59
8	50	90	85	2	780	69.67
9	70	90	90	3	780	75.34
10	70	90	90	3	400	72.63

3.5 Maximum yield using Nano MgO catalyst

A maximum yield of 78.58% was obtained using optimum operating parameters of temperature 55°C, reaction time 60 minutes, catalyst ratio 2 g, sample ratio 85 ml and stirring speed 590rpm.The effect of the different parameters on the actual yield RSM prediction is reported in table 3.3. It was observed that run 1 had the highest actual yield of 78.58% with reaction parameters, temperature 55°C, reaction time 60 minutes, catalyst ratio 2 g, sample ratio 85ml and stirring speed 590rpm.

Table 3.3: RSM Prediction using Nano CaO and MgO Catalyst

RUN	Temperature (°C)	Reaction time (min)	Sample ratio (ml)	Catalyst ratio (g)	Stirring speed (rpm)	Yield %
1	50	45	100	1.2	400	55.78
2	36.22	67	95	3	575	73.65
3	50	45	70	2	400	48.78
4	70	90	90	1.2	750	67.98
5	50	90	80	2	750	55.34
6	50	45	100	1.5	750	49.89
7	60	67	90	3	158	78.43
8	60	67	95	2	575	76.21
9	50	90	100	1.2	750	52.78
10	60	67	95	3	680	79.54
11	70	90	90	2	650	65.32
12	50	45	100	1.5	400	75.54
13	60	67	100	2	750	65.43
14	70	90	95	3	750	78.98
15	70	45	95	2	400	72.56
16	70	45	100	2	400	78.54
17	60	25	95	1.5	575	69.81
18	60	67	100	1.2	575	81.23
19	60	67	75	2	575	45.67
20	50	90	80	3	400	55.67
21	70	45	100	1.5	750	81.01
22	70	90	95	2	400	65.79
23	60	67	100	3	575	72.54
24	50	90	95	2	750	54.87
25	70	45	90	1	750	56.45

3.5 Maximum yield using Nano CaO and MgO catalyst

A maximum yield of 81.23% was obtained using optimum operating parameters of temperature 60°C, reaction time 67 minutes, catalyst ratio 1.2g, sample ratio 100ml and stirring speed 575rpm.The effect of the different parameters on the actual yield RSM prediction is reported in table 3.3 . It was observed that run 18 had the highest actual yield of 81.23% with reaction parameters, temperature 60 °C, reaction time 67 minutes, catalyst ratio 1.2g, sample ratio 100 ml and stirring speed 575rpm.

3.6 3D response surface plot of the effects of variables

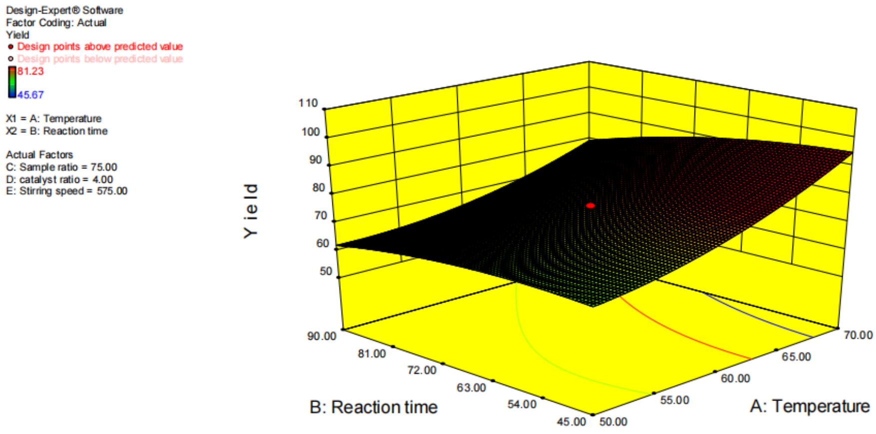

Fig 3.5: Effect of Reaction time and temperature

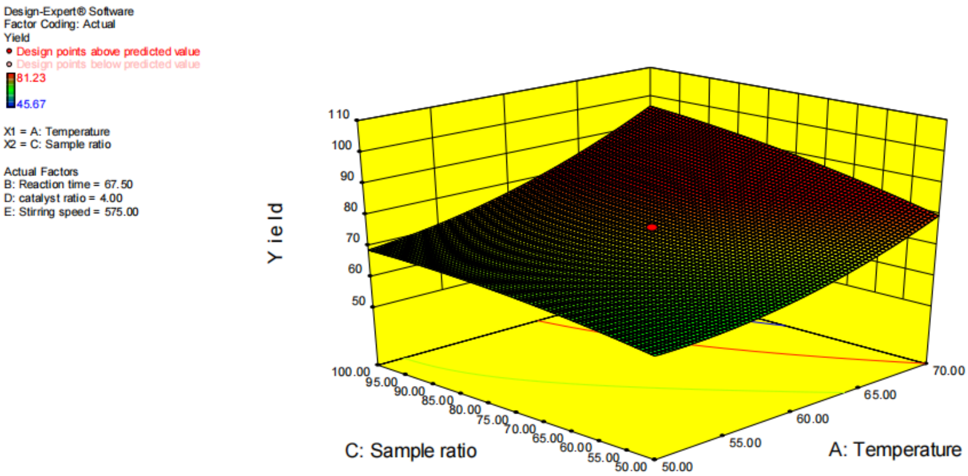

Fig 3.6: Effect of Reaction time and temperature

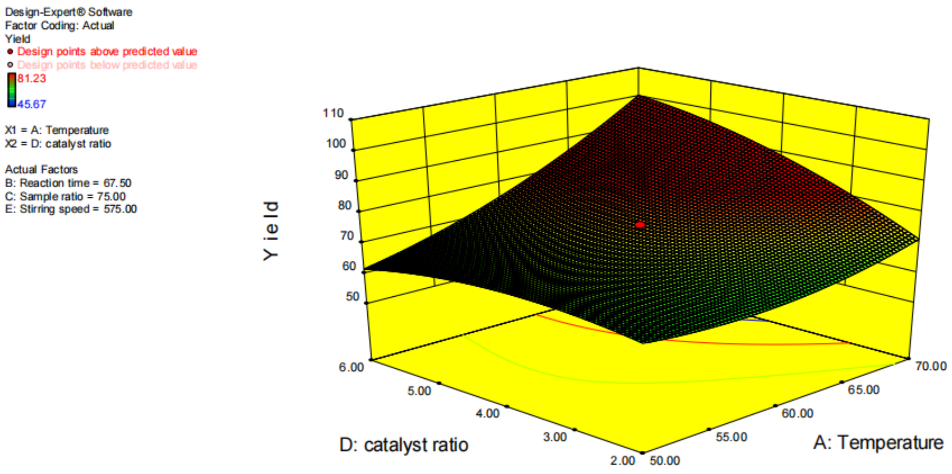

Fig 3.7: Effect of Catalyst ratio and temperature

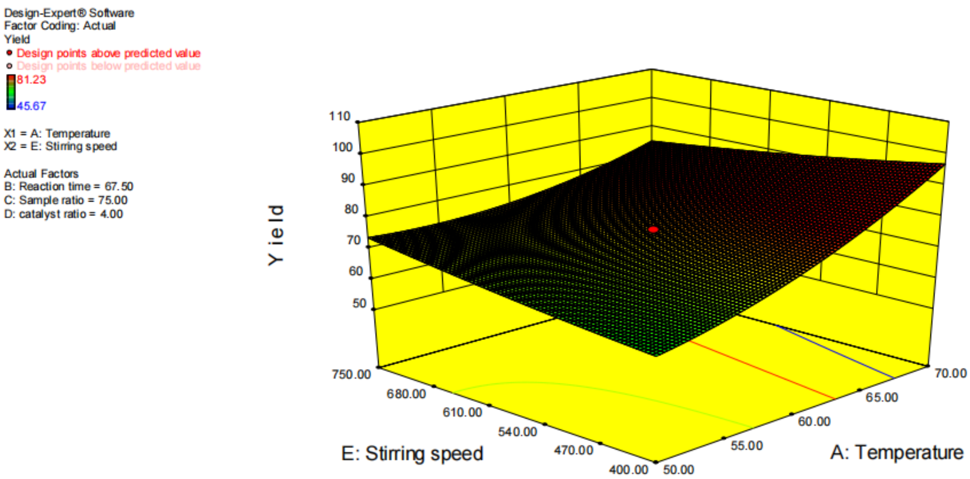

Fig 3.8: Effect of Stirring speed and temperature

3.7 Analysis using Design Expert (RSM)

- The interactive effects of adjusting the process variables within the design space were monitored using 3D surface plots. The analysis and optimization of waste cooking oil using nano catalyst CaO and MgO transesterification were completed using the Design Expert 8.0.7.1 and the graphical solutions presented in Fig 3.5 to Fig 3.8.
- Interactive ffect of temperature and reaction time on the yield shown in Fig 3.5.
- Effect of varying sample ratio and temperature on waste cooking oil transesterification shown Fig 3.6.
- Effect of varying catalyst ratio and temperature on waste cooking oil
- transesterification shown in Fig 3.7.
- Surface plot of the effect of interacting varying temperature and stirring speed
- shown in Fig 3.8.
- Surface plot of the interaction sample ratio and reaction time shown in Fig 3.5.
- Effect of interaction of catalyst ratio and reaction time shown in Fig 3.6.

3.8 Physical Properties of Biodiesel from Waste Cooking Oil using Nano Cao and Nano Mgo Catalysts

Table 3.4: Comparison of obtained Biodiesel and Diesel physical properties

Property	Diesel	Measured value of Biodiesel
Flash point	55(°C)	150(°C)
Viscosity	2.5-3.2 mm2/s	4.8 mm2/s
Cloud point	15(°C)	4(°C)
Pour point	8(°C)	-5(°C)
Density	0.84(gr/cm3)	0.87(gr/cm3)

- The flash point of base diesel and obtained biodiesel are mentioned in table 3.4,
- the obtained biodiesel has flash point as 150°C.
- The viscosity of base diesel and obtained biodiesel are mentioned in table 3.4,
- the obtained biodiesel has viscosity as 4.8 mm22/s.
- The cloud point of base diesel and obtained biodiesel are mentioned in table 3.4,
- the obtained biodiesel has cloud point as 4°C.
- The pour point of base diesel and obtained biodiesel are mentioned in table 3.4,
- the obtained biodiesel has pour point as -5°C.
- The density of base diesel and biodiesel are mentioned in table 3.4, the obtained
- biodiesel has density as 0.89 gr/cm3.

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IV. CONCLUSION

The findings demonstrate that the use of heterogeneous catalysts, specifically nano catalysts CaO and MgO, holds significant promise for biodiesel production. One of the primary advantages lies in catalyst regeneration, contributing to reduced catalyst costs and a simplified separation process, thereby lowering overall production costs. The results suggest that Nano CaO exhibits superior performance in terms of efficacy, reaction duration, repeatability of used catalyst weight percentage, methanol amount, and biodiesel production mass yield compared to self-combustion Nano MgO, attributed to its basic nature.While Nano MgO alone may not effectively catalyze transesterification due to its weaker basic affinity, when combined with Nano CaO, its surface structure enhances basic properties, making it a suitable base for the catalyst. This increased CaO contact surface results in a significant boost to transesterification reaction yield. Higher proportions of Nano CaO to Nano MgO further enhance biodiesel production mass yield. Additionally, the combined catalyst demonstrates better repeatability than Nano CaO alone.

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Mask-Wearing Behavior among Older Persons: Regional Differences in Europe

Cláudia Campos, MSc, Joana Carrilho, PhD, Luis Midão, PhD, Diogo Henriques, MSc & Elísio Costa, PhD

ABSTRACT

Background: The COVID-19 pandemic has emphasized the critical role of health behaviors, including mask wearing, in mitigating the virus's spread. This study aims to explore the association between the compliance with mask mandates and the European region of residence. Various factors, such as sociocultural, psychological, and contextual elements, can influence health behaviors.

Methods: The sample consisted of 50,900 European participants aged 55 years and above, drawn from the 8th wave of the SHARE survey. The average age was 75.89 years (SD=99.98), with 56.6% females. Statistical analysis focused on assessing the frequency distribution of COVID-19 preventative behaviors, particularly mask wearing. Cross-tabulation analysis and chi-square tests were employed to examine the relationship between country and mask wearing frequency. The contingency coefficient test was utilized to determine the strength of this relationship. Additionally, an ordinal regression analysis was conducted.

Keywords: geriatrics, public health, covid-19

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Mask-Wearing Behavior among Older Persons: Regional Differences in Europe

Mask-Wearing Behavior among Older persons

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Results: The findings demonstrated a statistically significant association between the European region and the frequency of mask wearing ($\chi^2 = 11978$, $df = 9$, $p < 0.001$). The contingency coefficient test revealed a moderate effect size ($C = 0.549$). Most participants reported 'Always' wearing masks (58%), followed by 'Often' (10.45%), 'Sometimes' (11.4%), and 'Never' (19.7%). Parameter estimates indicated significant variations between regions, with Eastern Europe being 97.8% less likely, Western Europe being 89.9% less likely, and Southern Europe being 56.4% less likely to fall into lower categories of mask-wearing compliance compared to Northern Europe.

Conclusions: This study highlights a significant association between the European region and mask-wearing frequency. Understanding and addressing sociocultural, psychological, and contextual factors within each region are crucial when implementing public health interventions. Targeted efforts should be made to enhance mask-wearing rates and mitigate the transmission of COVID-19. The findings underscore the importance of considering regional differences in compliance with mask mandates to develop effective strategies tailored to specific European regions.

Keywords: geriatrics, public health, covid-19.

Key points

- Paper addresses challenges and regional variations in COVID-19 mask-wearing.
- Cultural factors and individual beliefs shape mask-wearing, especially among older individuals.
- Older individuals in Eastern, Southern, and Western Europe have higher mask-wearing rates compared to those in Northern Europe

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I. INTRODUCTION

The emergence of COVID-19, caused by the novel coronavirus SARS-CoV-2, has posed a significant global public health challenge. Since its initial identification in late 2019, the virus has rapidly spread across the globe, leading to severe illness, overwhelming healthcare systems, and substantial mortality rates [1]. In response to this unprecedented crisis, governments and public health authorities worldwide have implemented various measures to mitigate the spread of the virus and protect public health [2]. These measures have included widespread testing, contact tracing, quarantine and isolation protocols, travel restrictions, and the promotion of personal protective measures, such as mask wearing and hand hygiene practices[3]. In the European Union (EU), individual member states have developed and implemented their own public health policies tailored to their respective contexts, while also adhering to guidelines and recommendations provided by the European Centre for Disease Prevention and Control (ECDC) and the WHO [4]. These policies aimed to reduce transmission rates, flatten the epidemic curve, protect vulnerable populations, and ensure the resilience of healthcare systems [5].

The implementation of personal protective measures, particularly mask mandates, during the COVID-19 pandemic has presented various challenges. Despite the importance of mask wearing in reducing virus transmission, there have been difficulties in ensuring widespread adherence and compliance to these measures. Studies have highlighted factors contributing to the challenges faced in implementing mask mandates, including a lack of consistent messaging, misconceptions about mask effectiveness, discomfort associated with prolonged mask use, and issues related to enforcement and public acceptance [6-8]. Additionally, variations in cultural norms, individual attitudes, and risk perceptions have influenced the acceptance and adoption of mask wearing [9, 10]. These complexities have underscored the need for clear communication strategies, education campaigns, and ongoing public health efforts to address misconceptions, promote mask use, and enhance compliance [11, 12].

The implementation of mask mandates, specifically among older persons individuals, has encountered specific challenges. Drawing on theories such as the Cultural Dimensions Theory, Health Belief Model, and Theory of Planned Behavior, several factors contribute to the difficulties faced in promoting mask-wearing behavior among older person population. According to the Cultural Dimensions Theory, cultural orientations and norms significantly influence health behaviors, including the acceptance and adoption of mask wearing [13]. Differences in cultural values, such as individualism versus collectivism, may impact the perception of personal responsibility and the willingness to comply with mask mandates [14]. Additionally, the Health Belief Model emphasizes individual beliefs and perceived susceptibility, severity, benefits, and barriers in shaping health behaviors [15]. Moreover, the Theory of Planned Behavior highlights the role of attitudes, subjective norms, and perceived behavioral control in determining behavioral intentions [16]. These theoretical frameworks suggest that cultural factors, individual beliefs, and perceived control play pivotal roles in shaping mask-wearing behavior among older persons. However, challenges remain, including issues related to accessibility, comprehension of guidelines, physical and cognitive limitations, and concerns about social stigma or discrimination [17, 18]. Addressing these challenges requires tailored communication strategies, clear guidelines, education programs, and support systems that consider the unique needs and circumstances of older persons.

The country or region where individuals live can serve as a reliable proxy for the social and cultural determinants of health behaviors. This approach is supported by numerous official documents and published studies that highlight the influence of sociocultural factors on health-related behaviors. The Cultural Dimensions Theory further emphasizes the impact of cultural orientations on health behaviors. For example, the World Health Organization recognizes that cultural norms, values, and practices significantly shape health behaviors and outcomes [19]. Cross-cultural studies have demonstrated variations in health behaviors, including mask wearing, across different countries and regions, reflecting cultural differences in attitudes, beliefs, and social norms [20-22]. These findings indicate Additionally, official documents such as national health surveys and reports provide insights into the social and cultural determinants specific to each country or region[23, 24]. By considering the country or region of residence, researchers can effectively capture the social and cultural context that influences health behaviors, providing valuable information for public health interventions and policies.

II. METHODOLOGY

The 8th wave of the SHARE (august 2020) survey featured a series of Covid-19 related questions, including some pertaining compliance with disease prevention behaviors.

Individuals with 55 years of age or older in 2020, that had responded the questionnaire individually, were included in the study. Descriptive bivariate statistics and ordinal logistic regression were performed to assess the relationship between independent and dependent variables.

III. INDEPENDENT VARIABLE

Introduction question regarding the country where the individual responded the survey from. Nominal variable that was coded into 4 categories to account for major European Regions: Eastern Europe (Czech Republic, Poland, Bulgaria, Romania, Slovakia) Northern Europe (Sweden, Denmark, Estonia, Lithuania, Finland, Latvia) Southern Europe (Spain, Italy, Greece, Portugal, Slovenia, Croatia, Cyprus, Malta) and Western Europe (Germany, the Netherlands, France, Switzerland, Belgium, Luxembourg).

IV. DEPENDENT VARIABLE

Health question originally phrased as "How often did you wear a face mask when you went outside your home to a public space?". An ordinal multiple choices with 4 levels: always, often, sometimes, and never. Refusals/non answers and missing values were excluded from the analysis. Refusals were incompatible with the ordinal interpretation of the variable and the type of statistical tests employed.

The methodology for this study involved analyzing information from a database of 50,900 individuals aged 55 years or older. Descriptive statistics were used to report the demographic characteristics of the sample, including age, gender, and country distribution. The frequency of Covid-19 preventative behaviors was assessed through self-reported measures, including mask wearing, hand sanitization, and attention to coughing and sneezing. Cross-tabulation analysis was conducted to examine the association between European region and the frequency of these behaviors, using chi-square and contingency coefficient tests. Furthermore, ordinal regression analysis was performed to investigate the relationship between mask wearing frequency and European region, controlling for other factors such as age and gender.

V. RESULTS

The individuals (n=50900) included in this database were 55 years or older, in average 75,89 years (SD=99,98), females (56,6%), mostly from Estonia (8.8%) Belgium (7.3%), and Greece (7.1%).

As shown on tables 1 and 2, from all the Covid-19 preventative behavior questions, the one relating to public mask wearing was the one with the lowest level of compliance, followed by the frequent usage of disinfection fluids and especial attention given to covering when coughing or sneezing.

Cross-tabulation analysis was conducted, as seen on table 3, to examine the association between country and frequency of mask wearing, frequency of hand sanitization usage, and increased attention to coughing and sneezing. The analysis included chi-square and contingency coefficient tests to assess the significance and strength of the relationship.

Results revealed a highly significant association between European region and frequency of mask wearing (χ^2 = 11978, df = 9, $p < 0.001$). The contingency coefficient test demonstrated a moderate effect size (C = 0.549), indicating a meaningful relationship between the variables.

These findings provide strong evidence of a statistically significant relationship between European region and frequency of mask wearing. The moderate effect size suggests that European region accounts for a substantial proportion of the variation in frequency of mask wearing. The remaining behavioral variables had significant but weak correlations: frequency of hand sanitization usage (χ^2 = 92.9, df = 3, $p < 0.001$, C=0.051) and increased attention to coughing and sneezing (χ^2 = 264.6, df = 3, $p < 0.001$, C=0.086)

In this study, we conducted an ordinal regression analysis to further investigate the relationship between frequency of mask wearing and European region. This analysis is resumed in table 4. A total of 41,387 valid cases were included in the analysis. The distribution of cases across the four regions was as follows: Eastern Europe (19.8%), Northern Europe (24.2%), Southern Europe (29.6%), and Western Europe (26.4%). Regarding mask wearing behavior, the majority of participants reported "Always" wearing masks (58%), followed by "Often" (10.45%), "Sometimes" (11.4%), and "Never" (19.7%). The final model demonstrated a significant improvement over the null model, as indicated by the likelihood ratio chi-square test statistic (χ^2 = 11096.097, df = 3, $p < 0.001$). The model fit the data well, as evident from the Pearson chi-square statistic (χ^2 = 6322.837, df = 6, $p < 0.001$) and the Deviance chi-square statistic (χ^2 = 5851.509, df = 6, $p < 0.001$). Pseudo R-squared measures were calculated to estimate the proportion of explained variance in the model. The Cox and Snell pseudo R-squared was 0.235, suggesting that the model accounted for approximately 23.5% of the variance in the outcome. The Nagelkerke pseudo R-squared was 0.251, indicating that the model explained approximately 25.1% of the variance. The McFadden pseudo R-squared was 0.097, signifying that the model explained 9.7% of the log-likelihood ratio.

The estimated parameters for the European region revealed important insights into the relationship with mask wearing. Controlling for other factors (sex, age), the results showed significant differences between the regions:

For individuals in the Eastern European region, the estimated parameter was -3.779 ($p < 0.001$), indicating a significantly lower likelihood (97.8% less likely) of being in lower categories of mask wearing compliance (never) compared to the baseline category – Northern Europe.

Individuals in the Western European region exhibited an estimated parameter of -2.429 ($p < 0.001$), suggesting a lower likelihood being (89.9% less likely) in lower categories of mask wearing compliance (never) compared to the baseline category.

Similarly, individuals in the Southern region had an estimated parameter of -0.829 ($p < 0.001$), indicating a lower likelihood (56.4% less likely) of being in lower categories of mask wearing compliance (never) compared to the individuals in Northern Europe.

These results provide robust evidence supporting the claim that the European region variable was associated with variations in the frequency of public mask wearing.

Overall, these findings highlight the importance of regional differences in predicting mask-wearing behavior, with individuals from the Eastern, Southern, and Western regions displaying higher likelihoods of mask-wearing compliance categories (always, often, sometimes) compared to individuals from Northern Europe.

It is important to acknowledge some limitations of our analysis such as the fact that the study relied on self-reported data, which can be subject to recall bias or social desirability bias. Also, our study utilized a cross-sectional design, which captures data at a single point in time, and only controlled for sex and age as covariates, but other factors that could influence mask-wearing behavior, such as socioeconomic status, education level, or cultural norms, were not included in the analysis. Finally, due to the decision to exclude missing values and refusals, a selection bias might have potentially been introduced. Future studies may benefit on focusing of the motivating factor for refusal and its inherent impact on mask wearing cultural perceptions.

VI. DISCUSSION

Mask-wearing has emerged as a crucial preventive measure in reducing the transmission of COVID-19. The use of face masks helps to mitigate the spread of respiratory droplets that may contain the virus, particularly in situations where physical distancing is challenging. Several official documents and published studies emphasize the effectiveness of masks in curbing transmission. For instance, the Centers for Disease Control and Prevention [25] in the United States has repeatedly stressed the importance of mask-wearing, highlighting its role in preventing the inhalation and exhalation of infectious particles. Additionally, a study by [6] conducted a comprehensive review of mask efficacy and reported that mask use, when combined with other preventive measures, can significantly reduce the risk of viral transmission. Despite the growing evidence, ensuring widespread adherence and compliance to mask mandates poses challenges. Cultural factors, individual beliefs, and regional differences can influence the acceptance and adoption of mask-wearing. The European Centre for Disease Prevention and Control (ECDC) has acknowledged these challenges, particularly among older persons, where cultural norms and personal attitudes may hinder compliance with mask mandates[26]. Overcoming these challenges requires tailored public health interventions that address cultural dimensions and health beliefs while promoting the importance of mask-wearing as a critical tool in preventing the spread of COVID-19.

Cultural norms, values, and practices play a pivotal role in shaping health behaviors, including mask-wearing. Understanding the influence of culture on health behaviors requires an exploration of cultural dimensions, as proposed by Hofstede's Cultural Dimensions Theory [13]. This theory identifies key dimensions that reflect cultural orientations, such as individualism versus collectivism, power distance, and uncertainty avoidance. These dimensions provide valuable insights into how cultural factors influence health-related attitudes and behaviors. For instance, in collectivist cultures, where emphasis is placed on the well-being of the community, mask-wearing may be more readily accepted and practiced as a collective responsibility to protect others. Conversely, individualistic cultures, which prioritize personal freedom and autonomy, may face challenges in promoting widespread adherence to mask mandates. The Cultural Dimensions Theory provides a framework to understand and navigate these cultural variations, enabling public health interventions to be tailored to specific cultural contexts. By recognizing and addressing cultural norms, values, and practices, health authorities can effectively communicate the importance of mask-wearing and encourage behavior change in a manner that aligns with diverse cultural orientations.

Theoretical frameworks such as Rosenstock's Health Belief Model (HBM) [15]and Ajzen's Theory of Planned Behavior (TPB) [16] provide valuable insights into understanding the factors that contribute to mask-wearing behavior among older persons. According to the HBM, individual beliefs about health threats, perceived susceptibility to those threats, and perceived severity of the consequences influence health-related behaviors. In the context of mask-wearing, older persons who perceive themselves as susceptible to COVID-19 and consider the disease as severe are more likely to engage in mask-wearing behavior.

Similarly, the TPB emphasizes the role of attitudes, subjective norms, and perceived behavioral control in shaping intentions and behaviors. Attitudes towards mask-wearing, including beliefs about its effectiveness and personal benefits, can strongly influence an individual's intention to wear masks. Subjective norms, such as the influence of social networks, family, and healthcare providers, also play a crucial role.

Moreover, perceived behavioral control, which refers to an individual's belief in their ability to perform the behavior, is another important factor. Older persons who feel confident in their ability to wear masks correctly and consistently are more likely to adhere to mask mandates.

By considering these factors, health authorities and policymakers can develop targeted interventions to promote mask-wearing among older persons. Educational campaigns that address beliefs, highlight susceptibility and severity of COVID-19, emphasize the positive attitudes towards mask-wearing, and promote subjective norms that encourage mask-wearing can effectively influence intentions and behaviors. Additionally, providing resources and support to enhance perceived behavioral control, such as offering accessible masks and proper instructions for use, can further facilitate adherence to mask-wearing guidelines.

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Our research on mask-wearing behavior among older individuals in different European regions revealed notable variations. In Eastern Europe, a high frequency of mask-wearing was observed, with approximately 85% of older individuals reporting regular use of masks in public settings. Northern Europe also exhibited a relatively high rate of mask-wearing, with around 80% of older individuals adhering to this preventive measure. In Southern Europe, the frequency of mask usage was comparatively lower, with approximately 60% of older individuals reporting regular mask-wearing. Western Europe displayed the lowest rate of mask-wearing among older individuals, with only around 40% adhering to this preventive behavior. These findings suggest that mask-wearing behavior varies across European regions, possibly influenced by cultural, societal, and contextual factors. Further research is necessary to delve into the underlying reasons for these variations and to design targeted interventions that address specific regional needs.

VII. CONCLUSION

This study examined the relationship between European region and mask-wearing behavior among individuals aged 55 years and older during the COVID-19 pandemic. The findings revealed significant regional variations in mask-wearing compliance. Individuals from Eastern, Southern, and Western Europe were more likely to report higher levels of mask-wearing compared to those from Northern Europe. Furthermore, consistently wearing masks was associated with significantly lower levels of non-compliance.

These findings underscore the importance of considering regional and cultural factors when implementing public health measures, such as mask mandates. The Cultural Dimensions Theory and other theoretical frameworks highlight the influence of cultural norms, beliefs, and values on health behaviors. Cultural differences in attitudes, risk perceptions, and individualism-collectivism orientations may contribute to variations in mask-wearing behavior.

Addressing the challenges associated with promoting mask-wearing among older persons requires tailored communication strategies, clear guidelines, and support systems that consider their unique needs and circumstances. Accessible information, education campaigns, and targeted interventions should be developed to address misconceptions, improve comprehension of guidelines, and alleviate concerns about social stigma or discrimination.

While this study provides valuable insights into the relationship between European region and mask-wearing compliance, there are limitations to consider. The findings may not be generalizable to the overall population, as the analysis focused on individuals aged 55 years and older. Additionally, measurement limitations and potential biases in self-reported behaviors should be acknowledged.

In conclusion, understanding the regional variations in mask-wearing behavior is crucial for developing effective public health strategies. By considering cultural and regional factors, policymakers and public health authorities can tailor interventions to promote mask-wearing and enhance compliance, ultimately contributing to the mitigation of COVID-19 transmission and protection of public health.

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Conflicts of interest

The authors declare no conflicts of interest.

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Author contributions

Cláudia Campos: conceptualization of the study, data analysis and draft of the main manuscript. *Joana Carrilho:* revision, and final approval of the work,

Luis Midão: revision, and final approval of the work.

Diogo Videira: revision, and final approval of the work.

Elísio Costa: revision, and final approval of the work.

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Why does this paper matter?

This paper matters because it provides evidence-based support for the effectiveness of mask mandates in reducing COVID-19 transmission, emphasizes the importance of mask-wearing as a preventive measure, and highlights the need for universal adoption of masks to protect both the public and healthcare workers.

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Impact statement

This article provides insights into the patterns of mask-wearing behavior among individuals aged 55 years and older in Europe, based on data from the Survey of Health, Ageing and Retirement in Europe (SHARE) survey database. By analyzing a large sample size of over 50,900 participants, this study sheds light on the adherence levels and regional variations in mask-wearing practices. The findings highlight the importance of regional differences in predicting mask-wearing behavior, emphasizing the need for tailored public health interventions and strategies across European countries. The results contribute to the existing knowledge on preventive measures during the COVID-19 pandemic and offer valuable information for policymakers, healthcare professionals, and researchers seeking to enhance public health preparedness and response.

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Effects of *Acacia Mearnsii* Tannins on Greenhouse Gas Emissions from Cattle Manure: A Anaerobic Digestion Study

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ABSTRACT

Anaerobic digestion represents an alternative for the treatment of waste, because in addition to allowing the reduction of the polluting potential of waste, it promotes the generation of biogas. The objective of this study was to evaluate the effect of diets with different levels of Acacia mearnsii tannins in two distinct cattle genotype on the greenhouse gas (GHG) emissions of cattle manure. Experimental batch-type digesters placed inside a climatic chamber (30 to 35ºC) were used for anaerobic digestion for 175 days. The digesters were organized in a completely randomized design, in a 2x4 arrangement, with two cattle genotypes (Holstein and Nellore) and four tannins level in the diet (0, 0.5, 1.0 and 1.5% of dietary DM), with four repetitions per treatment, totaling 32 experimental units. The data were subjected to analysis of variance (PROC MIXED), and the level effect was evaluated using orthogonal polynomials at 5% significance. Feeding cattle with Acacia mearnsii extract up to 1.5% of the DM of the diet does not harm the environment, as it does not alter the efficiency of removing nutrients from manure and the emission of GHG. The CH_4 and CO_2 production rates were higher for Holstein cattle, which may reduce Residence Time in the manure digestion process. Therefore, tannins can be used as additives to modify rumen fermentation without affecting the anaerobic digestion process of cattle manure.

Indexterms: *acacia mearsnii* extract, anaerobic digestion, carbon dioxide, cattle manure, greenhouse gas emissions, livestock nutrition, methane, nitrous oxide, rumen fermentation, tannins.

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Anaerobic digestion represents an alternative for the treatment of waste, because in addition to allowing the reduction of the polluting potential of waste, it promotes the generation of biogas. The objective of this study was to evaluate the effect of diets with different levels of Acacia mearnsii tannins in two distinct cattle genotype on the greenhouse gas (GHG) emissions of cattle manure. Experimental batch-type digesters placed inside a climatic chamber (30 to 35ºC) were used for anaerobic digestion for 175 days. The digesters were organized in a completely randomized design, in a 2x4 arrangement, with two cattle genotypes (Holstein and Nellore) and four tannins level in the diet (0, 0.5, 1.0 and 1.5% of dietary DM), with four repetitions per treatment, totaling 32 experimental units. The data were subjected to analysis of variance (PROC MIXED), and the level effect was evaluated using orthogonal polynomials at 5% significance. Feeding cattle with Acacia mearnsii extract up to 1.5% of the DM of the diet does not harm the environment, as it does not alter the efficiency of removing nutrients from manure and the emission of GHG. The CH_4 and CO_2 production rates were higher for Holstein cattle, which may reduce Residence Time in the manure digestion process. Therefore, tannins can be used as additives to modify rumen fermentation without affecting the anaerobic digestion process of cattle manure.

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I. INTRODUCTION

The livestock sector plays a vital role in climate change, representing 14.5% of human-induced greenhouse gas (GHG) emissions, according to Gerber et al. (2013). The majority of these emissions come from enteric fermentation and cultivated soils. The CH_4 and N_2O emissions are an environmental concern because their global warming potentials are 27.2 and 273 more potent than CO_2, respectively (Pörtner et al., 2023). Cattle manure, when stored, can represent 7 to 27% of the total CH_4 emission by ruminants (Hindrinchsen et al., 2006).

Cattle manure is a suitable substrate for developing anaerobic digestion, as it contains carbohydrates, proteins, and fat (Ahring et al., 2001). According to Moller et al. (2014), the effects of changes in livestock diets on biogas and GHG emissions need to be further studied, as many factors can change the

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characteristics of manure. As an alternative to the use of drugs to modify rumen fermentation and reduce CH_4 emissions, researchers have intensified the study of natural food additives for ruminants, such as tannins (Alves et al., 2017 and Perna Junior et al., 2022). These compounds are classified into hydrolysable (HT) and condensed (CT) tannins, both with effects depending on their plant source, concentration, and other factors such as the animal species, the physiological state, and the composition of the animal diet (Makkar, 2003a). According to Hao et al. (2011), CT in ruminant diets reduces the degradation of rumen N, but there is little research on how these phenolic compounds alter the decomposition of manure. Furthermore, Hegarty (2004), in his review of different genotypes and their impact on the digestive tract of ruminants, states that there are significant differences in digestive function between species, breeds and within breeds. Thus, there is a need to investigate how the use of tannins in the diet of different cattle influences the composition of manure and biogas production by anaerobic digestion.

Therefore, it is expected that the addition of tannins to the cattle diet will increase the N content of the manure and result in higher CH_4 emissions, as it enhances the anaerobic digestion process. The objective of the present study was to evaluate the nutrient removal efficiency and biogas production (CO_2, CH_4 and N_2O) during the anaerobic digestion of manure from two different groups of cattle fed with different levels of tannins from *Acacia mearnsii*.

II. MATERIAL AND METHODS

The trial was conducted in Pirassununga, state of São Paulo, southeastern Brazil (21°59'45"S, 47°25'37" W, and 625 m above sea level). All procedures involving animal care were conducted following the Institutional Animal Care and Use Committee Guidelines (protocol n° 3222290414).

The experiment was carried out in two phases: (1) the feeding phase and (2) the anaerobic digestion phase. In the first phase (the feeding phase), eight non-pregnant and non-lactating cows were used, four Holstein (*Bos taurus*) with a mean live weight of 775 (± 55) kg and four Nellore (*Bos indicus*) with an average live weight of 434 (± 47) kg. The choice of these two genotypes was because they are expressive representatives of the world's dairy production systems (Holstein genotype) and Brazil's large beef cattle sector (Nellore genotype). The cows were housed in individual stalls with a sand bed, feed bunker, drinker, and fans to ensure the animals' thermal comfort. Feed was offered twice daily for ad libitum intake (at least 5% refusal) at 8 am and 4 pm. It contained a mixed ration with a 50:50 roughage to concentrate ratio (DM-basis). The composition of the diet is shown in Table 1. The tannin doses (0, 0.5, 1.0 and 1.5%) were adjusted daily depending on DM intake and manually mixed with the total diet before each feeding. A commercial extract (Natur N, Seta®, Brazil) obtained from Acacia bark (*Acacia mearnsii*) was used as the source of tannins. The concentration of total phenols (84.4%) was determined by the Folin-Ciocalteau method (Makkar, 2003b), and the total tannins (82.3% equivalent in tannic acid) were estimated by the difference of the total phenol concentration before and after treatment with insoluble polyvinylpolypyrrolidone (Makkar et al., 1993). The CT concentration (32.3% equivalent to leucocyanidin) was determined by the HCl-butanol method, according to Makkar, 2003b. To avoid the negative effect of tannins on dry matter intake, low to moderate levels were used in this study, since Grainger et al. (2009) observed reduction in feed intake for dairy cow using only 0.9% of diet DM.

Table 1: Ingredient proportion and chemical composition of the experimental diet.

Item	Diet
Ingredient, % of dry matter (DM)	
Corn silage	50.0
Dry-ground corn grain	32.8
Soybean meal	12.7
Sodium chloride	0.5
Vitamin and mineral premix[a]	2.0
Tannins[b]	*
Caolim[c]	**
Chemical composition, % of DM	
DM (%)	61.1
Ash	6.6
Ether extract	3.2
Crude protein	13.1
Neutral detergent fiber	34.2
Acid detergent fiber	22.2
Nonfiber carbohydrates	43.0
Total digestible nutrients[d]	67.3

For the feeding and collecting feces, the animals were allocated in a duplicated Latin square 4x4 design, in a 2x4 factorial arrangement, with two distinct groups of animals and four levels of inclusion of tannins in the diet. Each experimental period had 22 days, the first 17 days for adaptation to the diet and the last five days for collection of feces, which were collected manually via rectum, at 8-h and 16-h, and frozen at -20° C forming a single sample composed of animals, in each period. Urine samples were obtained from all cows on the 22nd day of each experimental period, every 6 hours, during urination stimulated by massage on the vulva, and then stored at -20ºC in a single bottle, forming a sample composed of 24 hours.

In the second phase (the anaerobic digestion phase), the samples composed of feces and urine collected and frozen during the feeding phase (1) were diluted in water, adopting the total solids (TS) content of 6%. A theoretical manure ratio of 75:25 was used for the mixture of feces and urine, respectively. The substrate composition was 37.5% manure, 10% inoculum, and 52.5% water. Sludge from the manure treatment pond with the following characteristics was used as inoculum: pH = 6.2; TS = 4.61%; VS/TS = 60.30%. The digesters were organized in a completely randomized design, in a 2x4 arrangement, with two cattle genotypes (Holstein and Nellore) and four tannins level in the diet (0, 0.5, 1.0 and 1.5% of DM), with four repetitions per treatment, totaling 32 experimental units. The feces were loaded into batch-type digesters (Figure 1) consisting of a 75 mm reactor, a 100 mm gasometer, and a 150 mm digester made with three PVC pipes, adapted from Sunada et al. (2018). Anaerobic digestion was developed in mesophilic conditions (30 to 35ºC), ideal for digestion kinetics (Metcalf and Eddy, 2014), placing the digesters inside a climatic chamber with an electrical resistance heating system and a digital temperature controller, for 175 days. The treatments and respective characterization of the substrates are shown in Table 2.

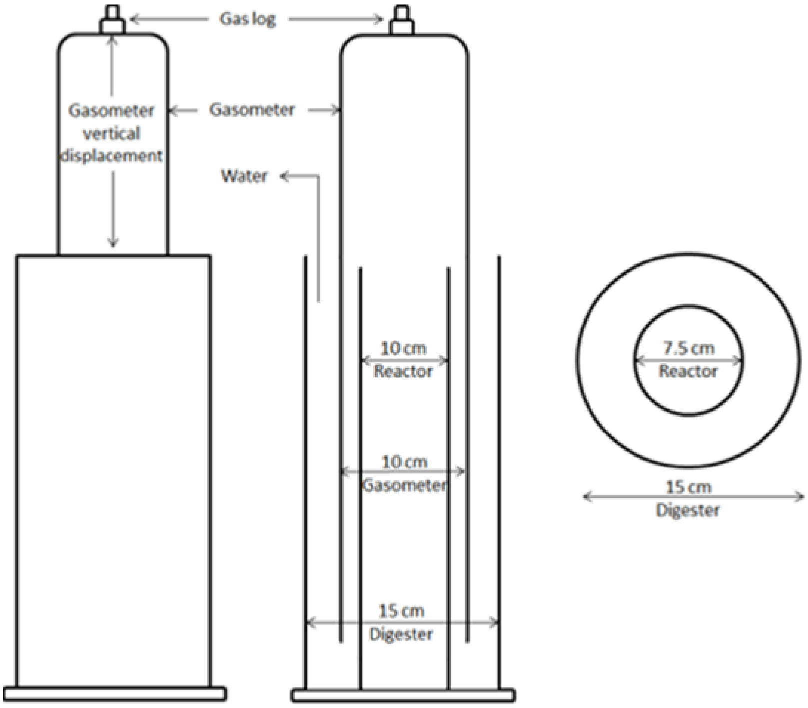

Figure 1: Anaerobic batch-type digester shown in front, side, and top views.

Biogas volume was determined by the displacement of the gasometer and its internal cross-sectional area, and corrected to 1 atm and 20ºC. The frequency of biogas measurement was conducted following gasometer capacity. Every time the biogas volume was measured, biogas samples were collected with a syringe connected to the gas log on top of the gasometer. The CH_4, CO_2 and N_2O concentrations were determined by gas chromatography (Trace 1300, Thermo Fisher Scientific®, Rodano, Milan, Italy), according to Kaminski et al. (2003).

Specific gas yield (per gram of VS fed or destroyed) was calculated by dividing the total gas production (L) by amount of volatile solids fed (before anaerobic digestion), or destroyed (difference between VS fed and eliminated). The test was finished when biogas production ceased. The nutrients fed and eliminated were weighed to calculate the DM content (grams).

The nutrients ingested and digested were calculated according to the following equation (Nogueira et al., 2023):

$$Nutrients\ (g) = \frac{nutrient\ fed\ or\ eliminated\ (\%) \times DM\ fed\ or\ eliminated\ (g)}{100}$$

Nutrient removals were calculated according to this equation:

$$Nutrient\ removal,\ \% = 100 - \frac{nutrient\ digestate\ (g)}{nutrient\ ingestate\ (g)} \times 100$$

$$Nutrient\ removal (\%) = \frac{nutrient\ fed\ (g) - nutrient\ eliminated}{nutrient\ fed\ (g)} \times 100$$

Individual feed and feces samples were collected before and after anaerobic digestion. The samples were dried in a forced-air oven, at 60°C for 48 hours, ground to 1.0 mm and analyzed. DM content was determined by method 930.15 of the Association of Official Analytical Chemists (AOAC) (Cunniff, 1995) in the forced-air oven at 105°C for 2 hours, followed by cold weighing. Nitrogen content was obtained by the micro Kjeldahl method, being multiplied by 6.25 to calculate crude protein (Cunniff, 1995). Neutral detergent fiber, acid detergent fiber, and lignin were determined by the methods described in the literature (Van Soest et al., 1991), using the Filter Bag and heat-stable α-amylase as in method 973.18 (Cunniff, 1995). The levels of total solid and volatile solids were measured according to the American Public Health Association (APHA) (Rice et al., 2012). The hydrogen ion potential (pH) was measured by a portable pH meter (Hanna Instruments®, HI 8424, Italy).

Table 2: Characteristics of the substrates and removal efficiency of nutrients in anaerobic batch-type digesters supplied with manure of Nellore and Holstein cattle fed *Acacia mearnsii* tannins

Variables	Genotype (G)		Tannin Level (TL)				SEM	Probability		
	Holstein	Nellore	0%	0.5%	1.0%	1.5%		G	TL	G*TL
Substrates (g kg^{-1})										
TS	45.5	49.3	49.3	47.6	47.5	45.2	-	-	-	-
VS	36.8	39.4	38.6	37.7	38.5	37.7	-	-	-	-
N (TS)	40.1	37.7	35.7	37.7	40.4	41.9	-	-	-	-
NDF (TS)	558.2	474.2	465.8	496.1	525.0	577.8	-	-	-	-
ADF (TS)	368.2	346.3	301.4	356.8	373.5	397.2	-	-	-	-
Eliminated nutrients										
TS (g)	71.40	79.75	78.65	77.91	76.91	75.03	2.07	0.003	ns	ns
VS (g)	51.55	56.72	54.85	54.92	53.97	55.81	1.73	0.005	ns	ns
N (g)	2.29	2.48	2.24	2.33	2.42	2.74	0.06	0.003	0.005^{L}	ns
NDF (g)	27.72	30.59	28.15	29.39	29.96	31.29	1.22	ns	ns	ns
ADF (g)	24.74	26.95	24.19	27.10	28.64	29.47	0.90	0.074	0.031^{L}	ns
pH	7.16	7.27	7.28	7.24	7.20	7.15	0.02	0.006	0.014^{L}	ns
Nutrient removal efficiency										
TS (%)	21.62	19.05	20.19	18.14	19.02	18.90	0.95	ns	ns	ns
VS (%)	29.99	27.07	28.90	27.20	29.86	25.85	1.06	ns	ns	ns
N (%)	38.22	30.82	36.50	36.61	35.47	29.42	1.72	0.029	ns	ns
NDF (%)	44.44	32.08	37.94	36.32	39.36	38.56	2.73	0.028	ns	ns
ADF (%)	32.63	20.64	20.95	20.90	22.28	21.75	2.67	0.003	ns	ns

*SEM: Standard error of the mean; G*TL: Interaction between Genotype and Tannin Level; TS: Total solids; SV: Volatile solids; N: Nitrogen; NDF: Neutral detergent Fiber; ADF: Acid detergent fiber.*

Data were statistically analyzed using the SAS 9.3 (SAS Institute Inc., Cary, NC, USA). Before the actual analysis, the data were analyzed for the presence of disparate information ("outliers") and normality of residuals (Shapiro-Wilk). Individual observation was considered an outlier when standard deviations to mean were more than +3 or less than −3. When the normality assumption was not accepted, the logarithmic transformation or the square root was required. The following statistical model was used:

$$Y_{ijkl} = \mu + G_i + L_i + G_i * L_i + P_k + A_l(G_i) + e_{ijkl}$$

Where Yijkl is the observation, μ is the general mean, Gi is the genotype effect (fixed effect), Lj is the tannin level effect (fixed effect), Gi* Lj is the interaction effect of genotype and tannin level, Pk is the period effect (random effect), Al(Gi) is the animal within genotype effect (random effect) eijkl is the residual error.

The data were subjected to analysis of variance (PROC MIXED), and the level effect was evaluated by the use of orthogonal polynomials, separating the effects in linear, quadratic and deviation from the quadratic. The 0.05 significance level was adopted.

Methane yield curve parameters were estimated from each digester yield using the Gompertz model (Kafle and Chen, 2016) according to the equation:

$$y_1 = A \exp exp\, [- B \exp exp\, (- k)\,]$$

Where y_1 is the methane yield at anaerobic digestion days, A is the asymptotic methane yield, B is the interaction constant, k is the yield constant rate, and exp is the base of natural logarithmic (2.7183).

$$t_1 = \frac{\ln ln\, B}{K}$$

Where t_1 is the point of inflection, ln is the logarithmic, B is the interaction constant, and k is the yield constant rate.

$$y_1 = \frac{A}{exp}$$

Where y_1 is the methane yield at inflection point, A is the asymptotic methane yield, and exp is the base of natural logarithmic (2.7183).

III. RESULTS AND DISCUSSION

The use of anaerobic digesters under controlled temperature conditions was a strategy of the present experiment to promote the maximum activity of the different microbial groups that convert the complex organic substrate into biogas through the anaerobic food chain, as the vast majority of anaerobic microorganisms they develop better at temperatures ranging between 20ºC and 40ºC (Gavala et al., 2003). According to Dohányos and Zábranská (2001), the efficiency of removal of organic matter (represented by the VS) is generally between 25-50% in reactors operated at mesophilic temperatures, in agreement with the values of approximately 30% found in the present experiment.

The pH, after the digestion process, was 1.54% higher for the Nellore than for the Holstein. Additionally, with increasing levels of tannins in the diet, there was a linear reduction in the pH of the degraded manure (Table 2). The different levels of tannins in the diet did not cause significant differences in nutrient removal efficiency. However, Holstein manure showed higher removal efficiency for N, NDF and ADF compared to Nellore (Table 2).

Hegarty (2004), in his review of the different genotypes and their impact on the digestive tract function of ruminants, states that there are significant differences in digestive function between species, breeds, and within breeds. Additionally, it is known that there are differences between zebu and taurine cattle regarding nutrient use and performance (Frisch and Vercoe, 1977). In the present experiment, it was observed that Nellore cattle (zebu) possibly had a better use of nutrients in the diet and, consequently, the generation of manure with fewer nutrients, which justifies having a worse efficiency in removing nutrients in the anaerobic digestion process, when compared to Holstein (taurine) manure (Table 2).

Cumulative CH_4 production was estimated by the Gompertz curve (Figure 2). The higher R^2 indicates that the Gompertz model was able to explain the variability in the response data. The Gompertz curve is an excellent modeling tool for predicting biogas yield. Kafle and Chen (2016) reported that Gompertz model was the better model to predict CH_4 yield compared to than others models. Holstein manure showed a higher growth rate (k) for CH_4 production (P<0.05) than Nellore cattle. Additionally, they had a shorter time to reach the inflection point (t). The inflection point (t) for CO_2 production was also lower (P<0.05). The proportion of CO_2 in percentage was linearly reduced (P<0.05) with increasing levels of tannins in the diet (Table 3).

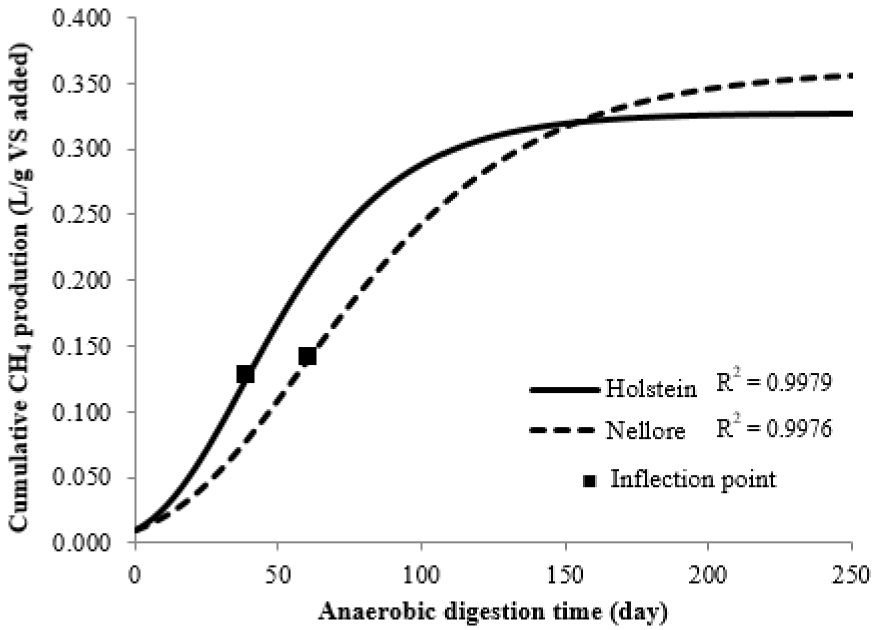

Figure 2: Cumulative CH_4 production, adjusted by the Gompertz model in anaerobic batch-type digesters supplied with manure of Nellore and Holstein cattle fed *Acacia mearnsii* tannins. The inflection point represents the day when the maximum point of CH_4 production occurred.

Tannins are known for the formation of complexes with dietary nutrients, especially with proteins, which can result in reduced nutrient digestibility and consequent increase in their excretion in feces, as can be seen in the present study, with an increase in the amounts of N, NDF, and ADF in the manure used to supply the anaerobic digesters (Table 2). According to Hristov et al (2013), the decreased nutrient digestibility is expected to increase fermentable organic matter concentration in feces (volatile solids), which can promote a tremendous anaerobic digestion for biogas production, including CH_4. However, the doses of tannins used in this study were not enough to modify the efficiency of nutrient removal.

Investigation of CH_4 production potential is a prerequisite to better predict CH_4 emission by anaerobic digestion or during storage of feces under anaerobic conditions. Moller et al. (2004) reported emissions of 0.4 L of CH_4 per gram of VS from bovine manure maintained in treatment systems with anaerobic lagoons, being close to 0.34 L/g of VS added, on average, found in the present study. However, it should be considered that the CH_4 yield of manure from different sources can be highly variable and is affected by several factors, including species, breed, animal growth stage, food, quantity and type of bedding material, as well as the degradation processes during pre-storage (Angelidaki and Ahring, 2000).

Unlike our hypothesis, tannins could not promote changes in CH_4 production. Hao et al. (2011), using 25g/kg of *A. mearnsii* CT for confined cattle, also found no increase in GHG emissions (CO_2, CH_4 and N_2O) when the manure was composted. However, Tseu et al. (2021), using the same tannin extract of this experiment (0, 0.75, 1.50, and 2.25% DM), had a quadratic effect on total biogas and CH_4 production when tannins are included above 0.75%, in addition, they suggest that tannin bioactive metabolites may appear in feces (when used to feed cows) and impair the digestion of the manure. A fact that may have contributed to the lack of change in CH_4 production in the present experiment may be due to the levels of inclusion of tannins in the diet of the animals, since these levels are considered low and were intentionally used for not cause the effect of reducing food consumption by animals due to the known astringent impact of these compounds (Grainger et al., 2009). The substrates of the different genetic groups evaluated showed that the growth rate of CH_4 and CO_2 production were higher for Holstein manure (Table 3), causing the time needed to reach the inflection point of the curve, or that is, the maximum production potential would occur 22 (Figure 2) and 25 days before the Nellore manure, respectively. This fact is of great relevance, as it can contribute to the reduction of the Residence Time (RT), which indicates the time in which the liquid fraction of manure remains in the digester in contact with the biomass (Metcalf & Eddy, 2014), being the time necessary to achieve a certain degree of waste treatment dependent on the microbial metabolism rate.

Table 3: Production of biogas, CH_4, CO_2 and N_2O in anaerobic batch-type digesters supplied with manure of Nellore and Holstein cattle fed *Acacia mearnsii* tannins

Variables	Genotype (G)		Tannin Level (TL)					Probability		
	Holstein	Nellore	0%	0.5%	1.0%	1.5%	SEM	G	N	G*TL
Biogas (L)	36.27	36.42	34.77	37.26	36.89	36.46	0.65	ns	ns	ns
CH_4	25.22	26.11	25.03	26.20	26.40	25.09	0.45	ns	ns	ns
CH_4 (%)	71.45	73.93	73.48	71.99	72.42	70.58	0.36	ns	ns	ns
CH_4/VS digested (L/g)	1.11	1.26	1.24	1.07	1.18	1.23	0.051	ns	ns	ns
CH_4/VS added										
A (L/g)	0.393	0.432	0.419	0.445	0.385	0.403	0.02	ns	ns	ns
t (day)	39.28	61.35	51.02	47.87	44.51	57.86	5.49	0.039	ns	ns
y (L/g)	0.145	0.162	0.154	0.163	0.142	0.145	0.006	ns	ns	ns
CO_2, L	11.00	10.87	9.99	11.05	11.58	11.11	0.21	ns	ns	ns
CO_2, %	28.54	28.15	27.09	28.06	29.28	28.92	0.21	ns	0.003^{L}	ns
CO_2/VS digested (L/g)	0.479	0.523	0.488	0.442	0.518	0.557	0.020	ns	ns	ns
CO_2/VS added										
A (L/g)	0.161	0.168	0.150	0.178	0.159	0.169	0.008	ns	ns	ns
t (day)	36.82	64.45	53.99	52.47	47.96	48.12	5.76	0.038	ns	ns
y (L/g)	0.059	0.061	0.055	0.065	0.059	0.062	0.003	ns	ns	ns
N_2O (mL)	8.02	8.95	8.868	6.948	9.336	8.784	0.38	ns	ns	ns
N_2O (%)	0.023	0.028	0.026	0.022	0.026	0.025	0.0013	0.064	ns	ns
N_2O/VS digested (mL/g)	0.362	0.496	0.461	0.391	0.428	0.437	0.030	ns	ns	ns
N_2O/VS added										
A (mL/g)	0.122	0.115	0.083	0.122	0.131	0.138	0.009	ns	ns	ns
t (day)	40.29	57.31	43.76	47.35	47.63	56.47	5.24	ns	ns	0.075
y (mL/g)	0.046	0.042	0.03	0.046	0.048	0.050	0.003	ns	ns	ns

*SEM: Standard error of the mean; G*TL: Interaction between Genotype and Tannin Level; A: Asymptotic production (L/g VS added); k: production constant (L/g of VS added per day); t: time at inflection point (day); y: production at the inflection point (L/g of VS added).*

As expected, in the present study the production of N_2O was not interfered by the type of substrate or by the tannin levels, probably because it occurs under strict experimental anaerobic conditions and due to the high C/N ratio. According to Bernet et al. (1996), when the C/N ratio is above 18 (characteristic of most animal manure) denitrification is complete and the formation of N_2O does not occur.

IV. CONCLUSIONS

Anaerobic digestion represents an alternative for waste treatment, as it not only reduces the polluting potential of waste, but also promotes the generation of biogas. The use of *Acacia mearnsii* extract up to 1.5% of the DM of the cattle diet did not promote changes in the nutrient removal efficiency, or in the production of biogas and its compounds (CH_4, CO_2 and N_2O). The production rates of CH_4 and CO_2 were influenced by the composition of the waste of the different groups of cattle evaluated, being faster for Holstein, which could be a positive factor for the reduction of the Residence Time. As there was no increase in GHG production, this is good for environmental issues. On the other hand, from the point of view of energy generation, it would be irrelevant. Therefore, this extract can be used as a food additive to modify rumen fermentation without modifying the anaerobic digestion process of cattle manure. Furthermore, we recommended more studies on livestock nutrition and anaerobic digestion of waste as an analytical tool to manage the sustainability of livestock production and the environment.

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