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A CORRELATION BETWEEN THE KAPPA NUMBER AND THE VENTORIM INDEX IN THE BLEACHING PROCESS

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ABSTRACT

The determination of the kappa number in the bleaching process is typically conducted with a pulp quantity between 3 and 4 grams, allowing for the calculation of values above four. However, after the oxidative extraction stage with hydrogen peroxide, the pulp presents a kappa number lower than this value. Therefore, the present study proposes a new method for determining the kappa number by creating the Ventorim bleaching index, which avoids the inconveniences associated with traditional kappa number analysis. For this study, industrial oxygen-delignified pulp was used. Four different ECF bleaching sequences were performed: OD(E+P)DD, OAD(E+P)DP, OADEDP, and OAEDP, along with the determination of the kappa number and the Ventorim bleaching index. The Ventorim index was based on the four chlorine-free bleaching sequences (ECF), all of which achieved a final brightness of 90% ISO, with very similar R^2 values and linear regressions. Consequently, a single equation was generated using all the data: Y=0.7202x+0.1464. This unified approach simplifies the analysis and broadens the applicability of the Ventorim bleaching index in the pulp and paper industry.

Keywords: Bleaching; Kappa number; Ventorim bleaching index

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UMA CORRELAÇÃO ENTRE O NÚMERO KAPPA E O ÍNDICE VENTORIM NO PROCESSO DE BRANQUEAMENTO

RESUMO – A determinação do número kappa no processo de branqueamento é, geralmente, realizada com uma quantidade de polpa absolutamente seca entre 3 e 4g e permite somente o cálculo de valores superiores a quatro. Entretanto, após o estágio de extração oxidativa com peróxido de hidrogênio, a polpa apresenta número kappa inferior a este valor. Deste modo, o presente trabalho propõe um novo método de determinação do número kappa, através da criação do índice Ventorim de branqueamento, que evita os inconvenientes gerados na análise do número Kappa. Para a realização do trabalho, foi utilizada uma polpa kraft industrial deslignificada com oxigênio. Foram realizadas quatro diferentes sequências de branqueamento ECF: OD(E+P)DD, OAD(E+P)DP, OADEDP e OAEDP e realizado a correlação do número kappa com o índice Ventorim de branqueamento. Tendo como resultado o índice Ventorim realizado nas quatro sequências de branqueamento livre de cloro molecular (ECF), sendo que todas as quatros sequências com alvura final de 90% ISO resultando uma correlação (R2) e uma regressão da reta muito semelhantes entre as mesmas. Concluindo assim, a possibilidade do uso de uma única equação referente a todos os dados, sendo a correlação representada pela equação Y= 0,7202x + 0,1464.

Palavras-Chave: Branqueamento; Número kappa; Índice Ventorim

1. INTRODUCTION

Since the last millennium, researchers have shown that the determination of the kappa number analyzes chemical compounds present in the pulp, such as lignin, hexenuronic acids, extractives, carbonyls, among others (Costa and Colodette, 2001; Correia et al., 2019).

These compounds can be oxidized by potassium permanganate under the conditions of the kappa number analysis. This analysis serves as a control for delignification in semi-chemical and chemical pulping processes and can be extended to the bleaching of chemical pulps. The kappa number determination was originally developed to quantify the residual lignin in pulp after pulping and bleaching processes (Costa and Colodette, 2001).

The most widely used standard for this purpose is the Technical Association Of The American Pulp And Paper Industry (TAPPI) standard, number 236 – om 85. Additionally, it is very common to use the kappa number after kraft pulping to control the pulping process and to study the pulping yield, often by fixing the kappa number (Ventorim et al., 2006; Correia et al., 2014; Secura et al., 2016; Correia et al., 2019).

In the bleaching process, according to the standard, the determination of the kappa number requires using an oven-dried pulp amount ranging from three to a maximum of four grams. This quantity of pulp allows for calculating a minimum kappa number of four. However, pulps after the oxidative extraction stage with hydrogen peroxide (E+P) typically present a kappa number lower than four. Despite this, it is common for many researchers to determine the kappa number in these pulps (Costa et al., 2003; Sevastyanova et al., 2012; Martino et al., 2013; Ribeiro et al., 2019).

However, for bleached pulps with a kappa number lower than four, a large amount of pulp is needed to conduct the analysis, leading to difficulties in homogenization due to the small amount of water relative to the required pulp quantity. Therefore, this method has the drawback of difficulties in the reaction between the reagents and the lignin, as well as other compounds oxidizable by potassium permanganate during the reaction, which can introduce errors in the analyses. Given these limitations, there is a need to develop a new approach that matches the kappa number analysis while addressing the issues presented.

The article proposes a new methodology for analyzing the kappa number using the Ventorim bleaching index, which avoids the inconveniences of conventional analysis while maintaining proportionality and enabling correlation between the methods through an equation.

2. MATERIAL AND METHODS

To conduct the study, an oxygen-delignified industrial kraft pulp was used, sourced from a eucalyptus pulp bleaching company located in Brazil.

Four different ECF bleaching sequences (OD(E+P)DD, OAD(E+P)DP, OADEDP e OAEDP, widely discussed in recent literature, were selected. (Camargo et al., 2019). The general conditions of the bleaching process for each sequence are shown in the (Table 1 to 4).

The stages outlined in Tables 1 to 4 were conducted in polyethylene bags with samples ranging from 50.0 to 300.0 g of absolutely dry pulp. Water was added to the pulp to adjust consistency, along with bleaching reagents and either sulfuric acid or sodium hydroxide to adjust the pH. After manual mixing, the pulp was preheated in a microwave oven to the desired temperature and then transferred to a thermostatically controlled steam bath, where it was maintained for the predetermined time.

After the reaction, samples of the residual liquor were taken for pH analysis and/

Table 1. General conditions of the bleaching process for the sequence $OD_0(E+P)D_1D_2$

Tabela 1. Condições gerais do processo de branqueamento da sequência $OD_0(E+P)D_1D_2$

Conditions	Bleaching stages			
	D_0	(E+P)	D_1	D_2
Consistency (%)	10	10	10	10
Time (min)	30	60	180	180
Temperature (ºC)	60	70	70	70
Final pH	3.0	11.5	3.8	4.5
NaOH ($kg*t^{-1}$)	-	8.0	Optimize	Optimize
H_2SO_4 ($kg*t^{-1}$)	Optimize	-	Optimize	Optimize
ClO_2 ($kg*t^{-1}$ as Cl_2)	FK[1]=0.2	-	15 or 20	Optimize
H_2O_2 ($kg*t^{-1}$)	-	3.0	-	-

[1] Kappa number

Source: Authors

Table 2. General conditions of the bleaching process for the sequence $OAD_0(E+P)D_1P$

Tabela 2. Condições gerais do processo de branqueamento da sequência $OAD_0(E+P)D_1P$

Conditions	Bleaching stages			
	A	D_0	(E+P)	D_1
Consistency (%)	10	10	10	10
Time (min)	120	30	60	180
Temperature (○C)	90	60	70	70
Final pH	3.0	2.5	11.5	3.8
NaOH ($kg*t^{-1}$)	-	-	8.0	Otimize
H_2SO_4 ($kg*t^{-1}$)	Otimize	-	-	Otimize
ClO_2 ($kg*t^{-1}$ as Cl_2)	-	FK[1]=0.2	-	Otimize
H_2O_2 ($kg*t^{-1}$)	-	-	3.0	-

[1] Kappa number

Source: Authors

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Table 3. General conditions of the bleaching process for the sequence OAD_0ED_1P

Tabela 3. Condições gerais do processo de branqueamento da sequência OAD_0ED_1P

Conditions	Bleaching stages				
	A	**D_0**	**E**	**D_1**	**P**
Consistency (%)	10	10	10	10	10
Time (min)	120	30	60	180	120
Temperature (ºC)	90	60	70	70	90
Final pH	3.0	2.5	11.5	3.8	11.0
NaOH ($kg*t^{-1}$)	-	-	8.0	Otimize	Otimize
H_2SO_4 ($kg*t^{-1}$)	Otimize	-	-	Otimize	-
ClO_2 ($kg*t^{-1}$ as Cl_2)	-	FK[1]=0.2	-	Otimize	-
H_2O_2 ($kg*t^{-1}$)	-	-	3.0	-	Otimize

[1] Kappa number

Source: Authors

Table 4. General conditions of the bleaching process for the sequence OAEDP

Tabela 4. Condições gerais do processo de branqueamento da sequência OAEDP

Conditions	Bleaching stages			
	A	**E**	**D**	**P**
Consistency (%)	10	10	10	10
Time (min)	120	120	120	120
Temperature (○C)	90	90	80	90
Final pH	3.0	11.5	4 - 5	11.0
NaOH ($kg*t^{-1}$)	-	8.0	Otimize	Otimize
H_2SO_4 ($kg*t^{-1}$)	Otimize	-	-	-
ClO_2 ($kg*t^{-1}$ as Cl_2)	-	-	20	-
H_2O_2 ($kg*t^{-1}$)	-	-	-	6.0

[1] Kappa number

Source: Authors

or residual chlorine dioxide or hydrogen peroxide. The pulp was washed with the equivalent of $9m^3$ of water per ton of absolutely dry pulp, simulating industrial conditions. After washing, the pulp was centrifuged to remove excess water and transferred to polyethylene bags, where it was dispersed and homogenized. Additionally, enough pulp sheets were prepared to perform five analyses of the kappa number, five of the Ventorim bleaching index, and five of brightness. Each stage was performed five times.

The kappa number was determined according to the guidelines of the TAPPI 236-om 85 standard, where a representative sample of the pulp was tested. The procedure followed, through trial or experience, involved dividing 50 mL by the estimated kappa number to obtain the dry weight and weighing it as accurately as possible to the estimated value; this was done to consume approximately 50% (volume)of the potassium permanganate solution used in the test, with the permanganate consumption by the test specimen expected to be between

30% and 70% (volume) of that observed with this standard.

Subsequently, a blank determination was performed using exactly the same procedure, but without the cellulose. In this case, the mixture must be titrated with the sodium thiosulfate solution immediately.

The new methodology proposed for determining the kappa number, namely the Ventorim bleaching index, was adapted from the TAPPI 236-om 85 standard, incorporating several modifications to address specific needs and limitations observed in traditional analysis methods. The determination was conducted using two grams of absolutely dry pulp from the sheets produced. A total of 440 mL of distilled water, 25 mL of 0.02 molar potassium permanganate, and 25 mL of 2 molar sulfuric acid were used.

After, 10 mL of 1 molar KI was added and titrated with 0.1 molar sodium thiosulfate, using 5% starch as an indicator. The blank determination was carried out as in the conventional test.

After conducting the tests, a linear regression graph was constructed relating the kappa number to the Ventorim bleaching index for each sequence. Subsequently, a single curve was determined between the sequences. An equation was then defined to allow the calculation of the kappa number from the Ventorim bleachability index.

3. RESULTS

The correlation between the Ventorim index and the kappa number for each bleaching sequence evaluated, all with a final brightness of 90%ISO, are shown in (Figures 1 to 4). Where, in the regression equation, x is the Ventorim bleaching index and y is the kappa number.

(Figure 1) shows the $OD_0(E+P)D_1D_2$ sequence, which is widely used in the pulp and paper industry and allows for the determination of four different kappa numbers. The kappa number results after the D_0, (E+P), D_1, and D_2 stages are distinct, enhancing the precision of an equation that converts the Ventorim index into a kappa number.

(Figure 2) illustrates the $OAD_0(E+P)D_1P$ sequence, which differs from (Figure 1) by incorporating an acid hydrolysis stage and a final peroxide stage to determine the kappa number.

(Figure 3) depicts the OAD_0ED_1P sequence,

Figure 1. Linear regression graph of the Ventorim bleaching index with the kappa number determined at the stages of the $D_0(E+P)D_1D_2$ sequence

Figura 1. Relação do índice Ventorim com o número kappa determinado nos estágios da sequência $D_0(E+P)D_1D_2$

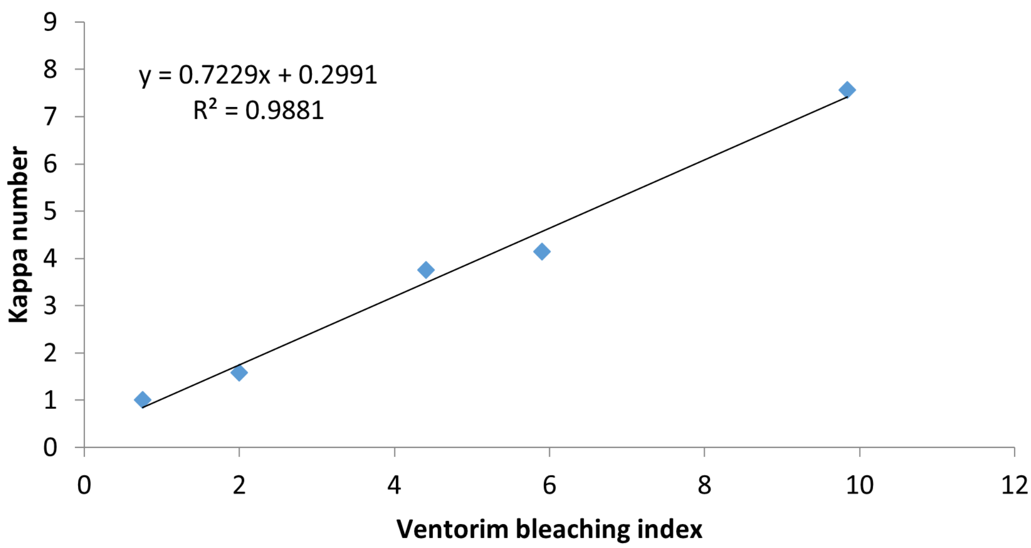

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Figure 2. Linear regression graph of the Ventorim bleaching index with the kappa number determined at the stages of the $AD_0(E+P)D_1P$ sequence

Figura 2. Relação do índice Ventorim com o número kappa determinado nos estágios da sequência $AD_0(E+P)D_1P$

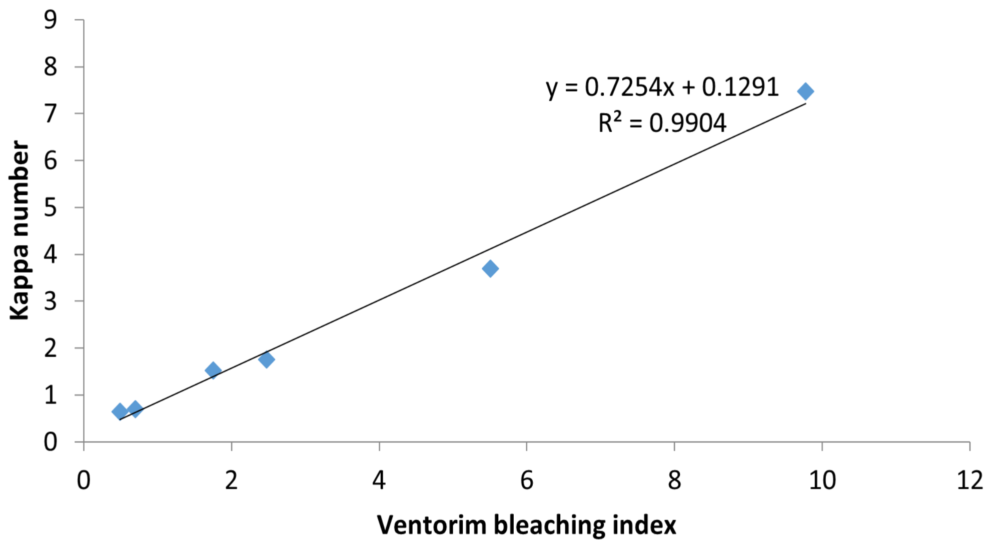
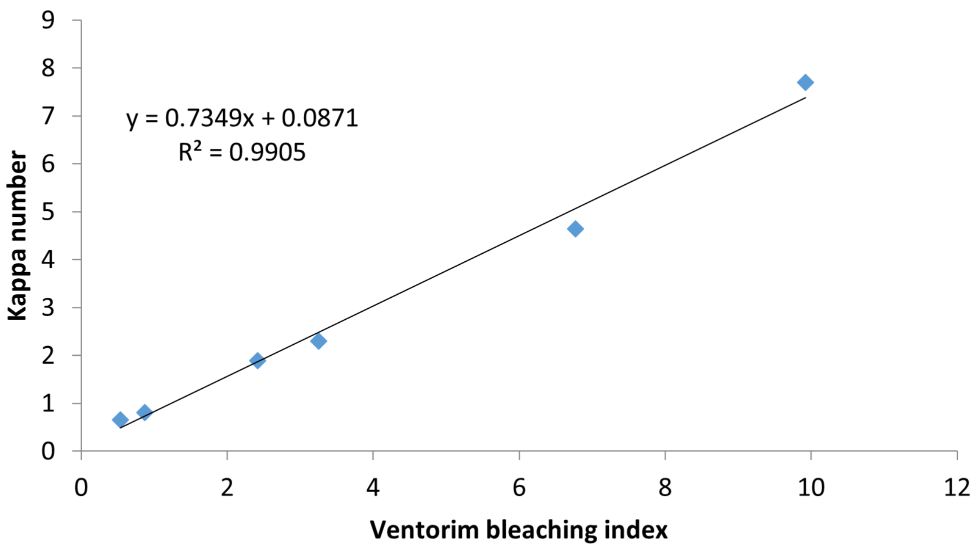


Figure 3. Linear regression graph of the Ventorim bleaching index with the kappa number determined at the stages of the AD_0ED_1P sequence

Figura 3. Relação do índice Ventorim com o número kappa determinado nos estágios da sequência AD_0ED_1P

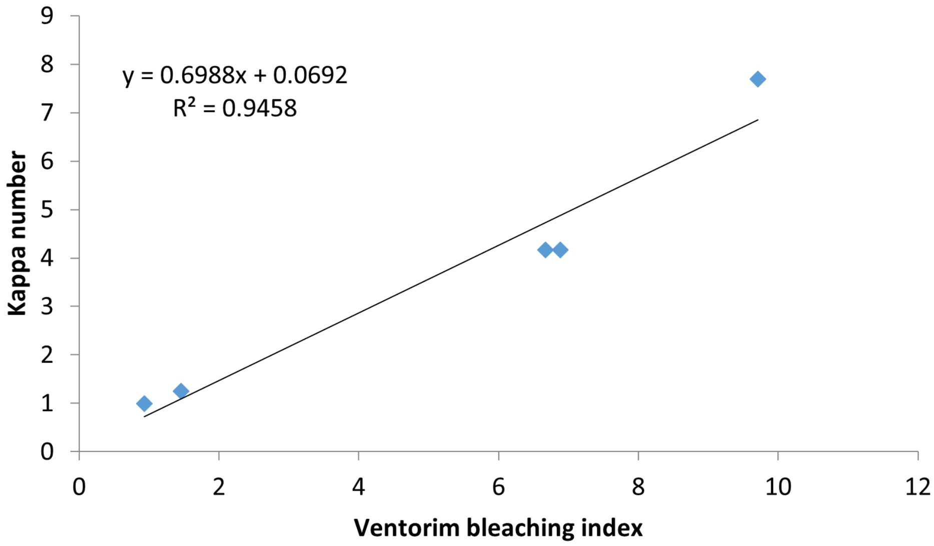


which differs from (Figure 2) only in the alkaline extraction stage, where hydrogen peroxide is absent.

(Figure 4) illustrates the OAEDP sequence, which introduces significant differences compared to (Figures 1 to 3). This sequence was analyzed to assess the similarity of linear regression results among the various bleaching sequences employed in this study.

Figure 4. Linear regression graph of the Ventorim bleaching index with the kappa number determined at the stages of the AEDP sequence

Figura 4. Relação do índice Ventorim com o número kappa determinado nos estágios da sequência AEDP



The results presented in (Table 5) are from the four different bleaching sequences, showing the R^2 values and the linear regression of each sequence.

Due to the high similarity in the R^2 values and linear regression of the four sequences, a regression analysis was conducted with all the data, as shown in (Figure 5), which resulted in an R^2 of 0.9791, and the equation generated by the linear regression was y = 0.7202x + 0.1464, a linear regression was obtained, which can be applied to the four different bleaching sequences in the study..

4. DISCUSSION

One of the advantages of using the Ventorim index is the reduced amount of pulp required compared to the kappa number, which uses a larger quantity of pulp in grams, thus complicating the analysis procedure.

Due to the significant difference obtained between the kappa number and the Ventorim index at all stages of the $OD_0(E+P)D_1D_2$ sequence, a linear regression was developed to correlate the two methods. To ensure that the regression would be valid for other sequences, three more different bleaching sequences were

Table 5. The R^2 values and the linear regression equations for the different bleaching sequences

Tabela 5. Os R^2 e as equações da regressão linear nas diferentes sequências de branqueamento

Bleaching sequences	R^2	Linear regression equations
$D_0(E+P)D_1D_2$	0.9881	Y=0.7229x + 0.2991
$AD_0(E+P)D_1P$	0.9904	Y=0.7254x + 0.1291
AD_0ED_1P	0.9905	Y=0.7349x + 0.0871
AEDP	0.9458	Y=0.6988x + 0.0692

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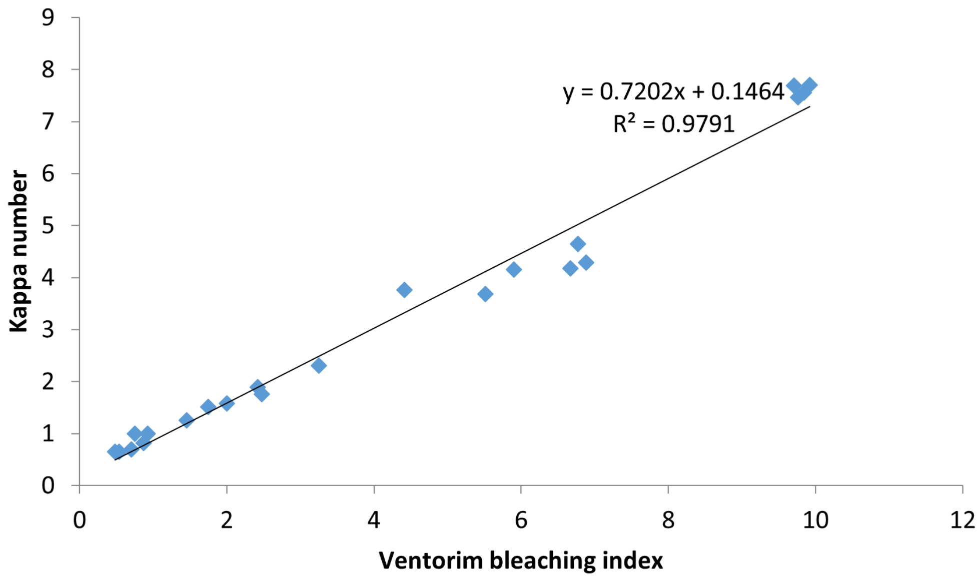
Figure 5. Linear regression graph of the Ventorim bleaching index with the kappa number with results from all stages of the four bleaching sequences

Figura 5. Relação do índice Ventorim com o número kappa com resultados de todos os estágios das quatro sequências de branqueamento



then performed.

Due to the strong similarity between the linear regressions, a single regression was proposed with all the data obtained in this study. To validate this regression, a test was performed on another pulp, showing a very small difference in the kappa number when compared to the Ventorim index. The equation $y = 0.7202x + 0.1464$ was used to convert the Ventorim index into the kappa number.

5. CONCLUSION

This study demonstrated that the new methodology for calculating the kappa number, the Ventorim bleaching index, is effective for pulps with up to 90% ISO brightness.

The equation $Y = 0.7202x + 0.1464$ relates the Ventorim bleaching index to the kappa number and shows a correlation above 97%.

The Ventorim bleaching index is easier to perform and uses less pulp, increasing the efficiency and accuracy of the determination for pulps with a low kappa number.

Additionally, only two grams of pulp bleached to 90% ISO brightness were used, whereas twenty grams of absolutely dry pulp were used to determine the kappa number for the same pulp.

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AUTHOR CONTRIBUTIONS

Ribeiro, VHH; Santos, EEGD; Alves, FCC; Santos, MVGD: Methodology, Formal analysis and Investigation. Favarim, HR: Writing - Review & Editing. Ventorim, G: Conceptualization, Writing - Original Draft and Supervision.

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