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# Perception of the Brazilian population related to COVID-19 vaccines on X (former Twitter): sentiment analysis

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## Abstract

**Objectives:** To analyze the perception of X/Twitter users regarding the COVID-19 vaccines made available by the Brazilian Ministry of Health. **Methods:** tweets published during the year 2021 made available by the Application Programming Interface of the Twitter platform were analyzed. The Python programming language was used for extracting and processing data, and the Power BI software was used for the generation of graphics. A *lexicon* in the Brazilian Portuguese language has been developed. The Extra Trees model was selected because it demonstrated the best performance among the models evaluated, showing a greater ability to correctly identify positive, negative, and neutral sentiments. **Results:** 2,202,571 tweets were extracted referring for the following vaccines: CoronaVac (642,465); AstraZeneca (472,449); Janssen (162,056) and Pfizer (952,601). In January 2021, more than 100,000 tweets related to CoronaVac were identified. Of these, 41.7% were related to positive sentiments and only 18.5% to negative sentiments. Considering the entire year of 2021, the Janssen vaccine among the more than 50,000 publications analyzed, 40.4% were neutral and 33.9% negative. In June 2021, a total of 101,952 vaccine-related posts were identified on the AstraZeneca vaccine, 63.66% with neutral sentiments. Regarding the posts of the Pfizer vaccine, on May 1, 2021, a total of 124,058 posts were found, being found approximately 54.52% of the posts associated with neutral feeling. **Conclusion:** most of the sentiments obtained for all vaccines were neutral, however it was also possible to observe that the CoronaVac, despite the negative publicity, was widely accepted by the population having most of the sentiments expressed in a positive way if considered with the data of the other vaccines.

**Keywords:** COVID-19, Vaccines, COVID-19 Vaccines, Sentiment Analysis, Social Media.

# Percepção da população brasileira em relação às vacinas contra a COVID-19 no X (antigo Twitter): análise de sentimentos

## Resumo

**Objetivo:** Analisar a percepção dos usuários do X/Twitter em relação às vacinas contra a COVID-19 disponibilizadas pelo Ministério da Saúde do Brasil. **Métodos:** Foram analisados tweets publicados durante o ano de 2021, disponibilizados pela Interface de Programação de Aplicações (API) da plataforma Twitter. A linguagem de programação Python foi utilizada para extração e processamento dos dados, e o software Power BI foi utilizado para a geração dos gráficos. Um léxico na língua portuguesa brasileira foi desenvolvido. O algoritmo Extra Trees foi selecionado por apresentar o melhor desempenho entre os nove modelos avaliados, mostrando maior capacidade de identificar corretamente sentimentos positivos, negativos e neutros. **Resultados:** Foram extraídos 2.202.571 tweets referentes às seguintes vacinas: CoronaVac (642.465); AstraZeneca (472.449); Janssen (162.056) e Pfizer (952.601). Em janeiro de 2021, foram identificados mais de 100.000 tweets relacionados à CoronaVac. Destes, 41,7% estavam relacionados a sentimentos positivos e apenas 18,5% a sentimentos negativos. Considerando o ano de 2021, a vacina da Janssen, entre as mais de 50.000 publicações analisadas, teve 40,4% de sentimentos neutros e 33,9% negativos. Em junho de 2021, foram identificadas 101.952 publicações relacionadas à vacina AstraZeneca, sendo 63,66% com sentimentos neutros. Em relação às postagens sobre a vacina da Pfizer, em 1º de maio de 2021, foram encontradas 124.058 postagens, sendo aproximadamente 54,52% associadas a sentimento neutro. **Conclusão:** A maioria dos sentimentos obtidos para todas as vacinas foi neutra. No entanto, também foi possível observar que a CoronaVac, apesar da publicidade negativa, foi amplamente aceita pela população, tendo a maioria dos sentimentos expressos de forma positiva, se considerados em comparação com os dados das outras vacinas.

**Palavras-chave:** COVID-19, Vacinas, Vacinas contra COVID-19, Análise de Sentimentos, Mídias Sociais.

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## Introduction

In December 2019, SARS-Cov-2, a new coronavirus of the *Coronaviridae* family, was identified as the cause of complications of the pulmonary pathway in humans and in 2020 the World Health Organization (WHO) declared a COVID-19 pandemic, due to the rapid spread of the virus around the world[1]. According to the WHO, the first confirmed case of Covid-19 in Brazil occurred on February 26, 2020, in the city of São Paulo. After confirmation of the case, other cases began to be registered in the country, with São Paulo as the epicenter of the disease.

Studies suggest that between 2020 and 2022 the Covid-19 pandemic and vaccines have become one of the main topics of discussion on social media[2,3], subject that was influenced by debates in the media and at the same time capable of influencing the behavior of citizens in the face of vaccine development and vaccination campaigns.

The widespread impact of COVID-19 on daily life and collective behavior sparked a variety of public debates. These debates, disseminated by both healthcare professionals and laypersons, were widely shared across social media platforms. Among them, Twitter (recently rebranded as X) emerged as one of the primary platforms for such discussions, with over 217 million users globally and approximately 19 million users in Brazil[4].

Jang and collaborators (2020) observed that most of the comments related to Covid-19 on Twitter before the emergence of the first vaccines were about public health interventions such as distancing and social isolation, hand hygiene and the use of masks. However, in relation to the analysis of users' sentiments, most comments were considered negative and were related to the general outbreak and lack of information[4].

In Brazil, given the scenario marked by the government's denialism, the phenomenon known as the *infodemic* highlighted the dissemination of fake news by political leaders, which confronted scientific evidence about the treatment and control of Covid-19 through social networks[5]. This phenomenon led the population to doubt the importance, safety and efficacy of vaccines, which meant a major threat to public health[6].

Sentiments related to these topics may or may not be related to adherence to vaccination and consequently impact the contagion and progression of the disease[7]. It is important to highlight that Brazil, with a population of 213 million inhabitants, ranks seventh in the world in terms of population size, as reported by the Brazilian Institute of Geography and Statistics in 2022. However, despite representing only 2.66% of the global population, the country accounted for 5.48% of all COVID-19 deaths worldwide between 2020 and 2021, according to the World Health Organization.

Considering the need to identify, understand, and analyze public perceptions, concerns, and sentiments regarding COVID-19 vaccines on social media, this study provides a comparative examination of four distinct vaccines, thereby broadening the understanding of public sentiment toward each one. These findings also offer practical implications for public health campaigns, particularly within the Brazilian context. In light of this, the objective of this study was to analyze the sentiment of Twitter users in relation to the COVID-19 vaccines made available by the Ministry of Health of Brazil.

## Methods

A sentiment analysis study was carried out. Sentiment Analysis (SA) can be understood as assigning a value to each word contained in a text, with the aim of analyzing the sentiment that wants to be expressed in it and identifying the most quoted topics. In other words, words with a negative sentiment will be assigned negative values and words with a positive sentiment will be assigned positive values[8]. The use of SA enables psychometric delimitation on a given topic and its results make a valuable contribution to the scientific environment[9].

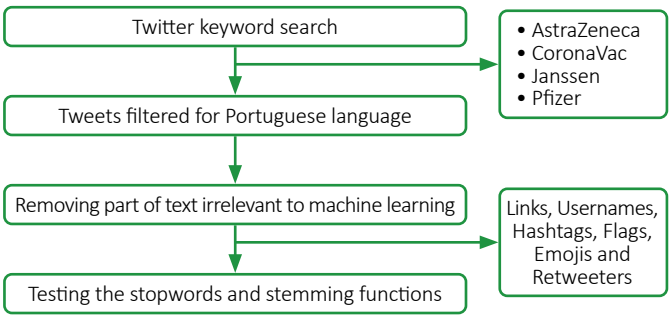
### 2.1 Data extraction and pre-processing

For the realization of this study were considered tweets published between January 1, 2021, and December 31, 2021 made available by the *API* (*Application Programming Interface*) of the Twitter platform. Twitter was chosen due to the availability of access to its API, in addition to the scope and relevance of the platform in the debates on vaccines for COVID-19. For the extraction of tweets, 4 keywords were defined: "AstraZeneca", "CoronaVac", "Janssen" and "Pfizer", referring to the vaccines authorized by the Ministry of Health for use in the Brazilian population, in 2021[10]. During the tokenization stage, the *gsub* function in R (R Foundation for Statistical Computing) was used to extract the tweets whose language field in the tweets metadata was specified as Portuguese[11,12].

In the process of extracting and processing data, the Python programming language, and the Power BI software were used for the generation of graphics. In total, 186 thousand tweets were collected per month, comprising an average of 6 thousand posts per day, in return for each keyword. This amount was defined according to the requisition limits imposed by the API. In relation to the treatment of the data obtained, functions were used that removed part of the content of the posts that was considered irrelevant to machine learning, such as: links, usernames, hashtags, signage, emojis and *retweetes*. Figure 1 presents the steps undertaken in the data preprocessing process.

Other functions, such as *stopwords* removal (which excludes articles, prepositions, and pronouns) and *stemming* (which removes prefixes and suffixes), were initially tested. However, their performance in Portuguese proved insufficient. Widelyused NLP libraries, such as NLTK and spaCy, still offer limited and sometimes imprecise support for Portuguese morphological processing, which can lead to semantic distortion in short texts such as tweets. Given the unsatisfactory preliminary results and the potential loss of contextual meaning, these techniques were not adopted in the final preprocessing pipeline.

**Figure 1.** Data pre-processing flowchart

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### 2.2 Model training

Considering that at the time of this study and to the knowledge of the authors there was no lexicon in the Brazilian Portuguese language available in the literature, it was necessary to create a *lexicon* by creating a list of words to train the algorithm. To do this, posts published between January 1, 2022 and January 5, 2022 were extracted, so as not to influence the evaluations of posts from 2021, and the keywords "AstraZeneca", "CoronaVac", "Janssen" and "Pfizer" were used.

The extraction resulted in a set of 5,000 tweets, a volume that enabled careful evaluation by two independent raters and ensured consistency in the training data. Preliminary tests indicated that this sample size provided stable model performance, balancing methodological rigor and practical feasibility. These tweets were manually analyzed by two independent researchers and classified according to their polarity, with any discrepancies resolved by consensus. For this purpose, three categories were adopted: (1) positive when they expressed an opinion in favor of vaccines; (2) neutral when they were non-opinionated posts, such as news, informative posts from public organizations and posts that used keywords in search of engagement; and (3) negative when they expressed sentiments of objection about vaccines.

After constructing the lexicon, nine sentiment classification models were tested to identify the most suitable approach for this study. The models evaluated were: "Decision Tree Classifier", "Extra Trees Classifier", "Gradient Boosting Classifier", "K-Nearest Neighbors Classifier", "Logistic Regression", "Multilayer Perceptron Classifier", "Multinomial Naive Bayes", "Random Forest", and "Support Vector Machine". The "Extra Trees Classifier" was selected, as it achieved the highest performance, with an accuracy of 60.49% in classifying tweets as positive, negative, or neutral.

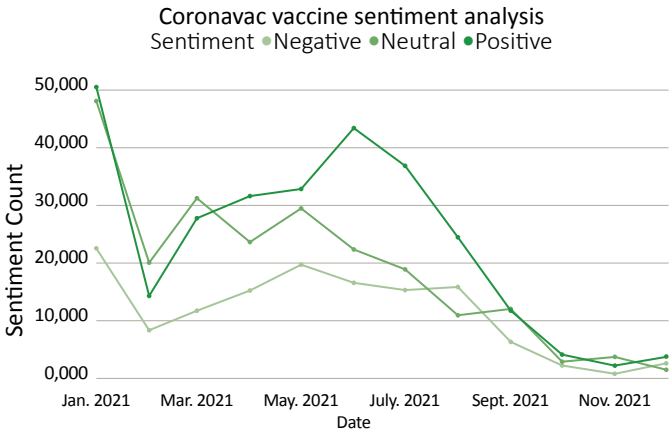
The extra tree classifier model is a variant learning model of Random Forest and only differs in the form of construction of decision trees. Initially each extra decision tree is built from the original training sample, including all the data obtained from the search. Then a random cutoff point is selected for each descriptor, with subsequent optimization limited to the choice between these partitions[13]. For example, the implementation of the extra classification model was used in this project to classify the sentiments contained in twitter posts, in this case the cut made from this model divides the posts as to positive, negative and neutral sentiments.

## Results

A total of 2,229,571 tweets were extracted, distributed as follows: CoronaVac (642,465), AstraZeneca (472,449), Janssen (162,056), and Pfizer (952,601).

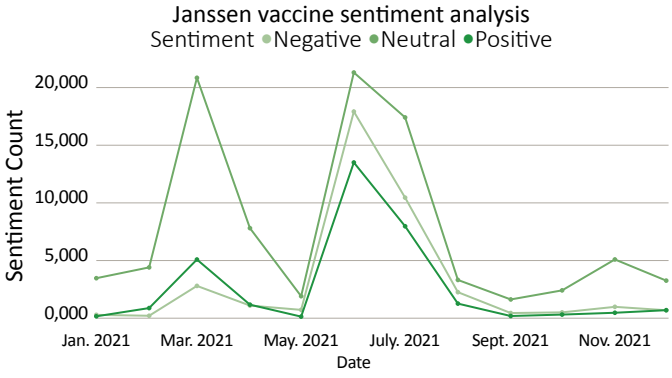
Coronavac was the first vaccine made available in Brazil. In January 2021, over 100,000 posts related to the vaccine were identified. Of these, 41.7% (50,526) expressed positive sentiment, while only 18.5% (22,416) conveyed negative sentiment. Neutral sentiment showed two peaks, in March and November, whereas negative sentiment remained relatively stable throughout the year (Figure 2).

**Figure 2.** Monthly frequency of Sentiments of the Coronavac Vaccine on tweets posted from January 1, 2021, to December 31, 2021.




Janssen was introduced in Brazil by the MoH in June 2021. Sentiment analysis of tweets related to this vaccine revealed that positive reactions were less frequent compared to neutral and negative ones, especially during March, June, and November 2021. Throughout the year, among over 50,000 posts, 40.4% (21,281) were neutral, and 33.9% (17,887) were negative (Figure 3).

**Figure 3.** Monthly frequency of Sentiments of the Janssen Vaccine on tweets posted from January 1, 2021, to December 31, 2021.




AstraZeneca became available in March 2021. The majority of tweets related to this vaccine expressed neutral sentiment. Two significant peaks in post volume were observed, one in January 2021 and another between May and June 2021, with both periods dominated by neutral content. In January 2021, among 62,689 tweets, 90.83% (56,946) were neutral, 7.14% (4,479) were positive, and 2.01% (1,264) were negative. In June 2021, 101,952 tweets were identified, of which 63.66% (64,904) were neutral, 18.16% (18,519) positive, and 18.17% (18,529) negative (Figure 4).

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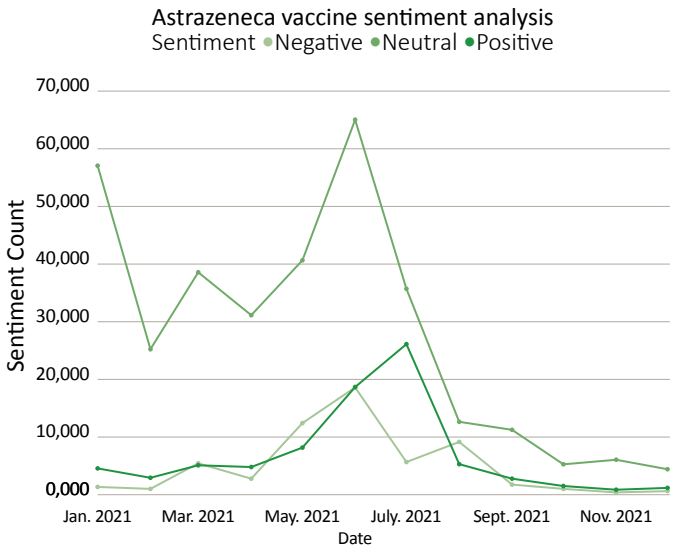
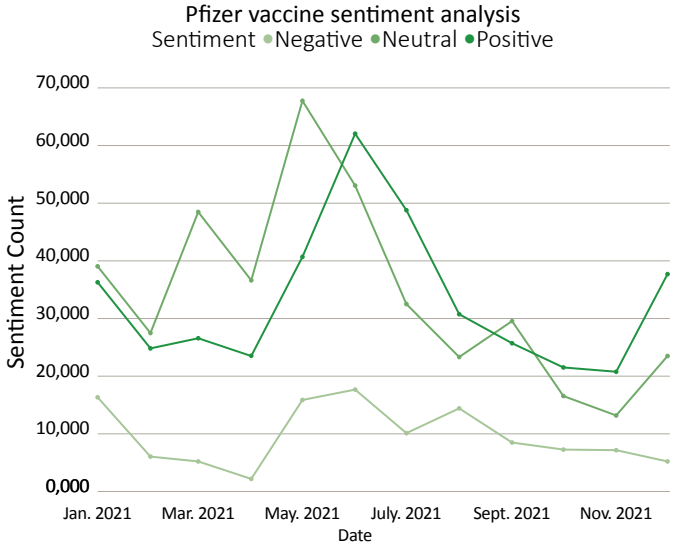
**Figure 4.** Monthly frequency of Sentiments of the AstraZeneca Vaccine on tweets posted from January 1, 2021, to December 31, 2021.




Throughout the study period, Pfizer-related tweets had a high proportion of positive and neutral sentiments. On May 1, 2021, a total of 124,058 posts were recorded: 54.52% (67,646) were neutral, 32.72% (40,603) positive, and 12.74% (15,809) negative. On June 1, 2021, 132,524 posts were identified, with 46.77% (61,991) expressing positive sentiment, 39.95% (52,948) neutral, and 13.26% (17,585) negative (Figure 5).

**Figure 5.** Monthly frequency of Sentiments of the Pfizer Vaccine on tweets posted from January 1, 2021, to December 31, 2021.




## Discussion

According to our knowledge, this is the first study conducted in Brazil with the objective of verifying the feeling of the population in relation to COVID-19 vaccines that covered the twelve months of the first year of vaccination[14-27].

The debate on the acceptance of vaccines is not a recent topic and has been mainly related to the anti-vaccine movement, which is totally contrary to the use of vaccination as disease prevention, a decision that may (or may not) be related to the effectiveness of vaccines. Some studies indicate that public acceptance of vaccines can vary, often influenced by perception, media coverage, and circulating information about each vaccine, rather than strictly by their biological efficacy[18-20].

Recently, a systematic review carried out by Roy and collaborators (2022) on aspects that influence the adherence and acceptance of the COVID-19 vaccine in several countries showed that the main reasons for not taking doses of the new vaccines were related to the safety of the vaccine, with special attention to the possible side effects[20].

The vaccines distributed in Brazil were developed and tested throughout 2020, and although the production of some of them took place outside the country, all were tested in Brazilian volunteers. This, associated with the wide dissemination of international news, took information on safety issues related to vaccines to a wide audience, directing at various times the debate to possible adverse events. In this scenario, the Coronavac vaccine was the first to be approved for emergency use in Brazil, on January 17, 2021. Its technology is based on the presence of the inactivated virus antigen, and immunization is reached in two doses, administered in an interval of 28 days in children from 3 years old and between 2 and 4 weeks in adults[21].

Coronavac vaccine was widely mentioned on social media in Brazil. A study by Carvalho et al (2022) shows that this immunizer was the most cited on *Instagram* and *Facebook*, being mentioned 14,617 times on these social networks on the day the vaccination began[21]. In the present study, Coronavac was the second vaccine in number of tweets and a predominance of positive sentiments towards was observed. A hypothesis for this finding is the initial availability of the vaccine: Coronavac was the first vaccine to be applied to Brazilian citizens from public vaccination campaigns. For a few weeks, it was the only vaccine available, in a scenario in which there was a delay in the start of national vaccination[22].

Despite the predominance of positive sentiments, some studies show that Coronavac was the most despised immunizer during the pandemic[5,23]. The immunizer manufactured by the Butantan Institute in partnership with the Chinese laboratory Sinovac, was usually referred to by Brazilian government officials, including the president and his supporters, as “the Chinese vaccine” or “vachina”, to disqualify the immunizer, due to the idea that China was responsible for the origin and spread of the vírus[5,24]. This behavior led to an increase in vaccine hesitancy among the Brazilian population and a certain resistance to the use of the Coronavac vaccine[23].

Although Coronavac received the company of the other three vaccines in the first quarter of 2021 and presented lower effectiveness results than those of Pfizer, AstraZeneca and Janssen vaccines, the positive sentiments of Twitter users were preponderant throughout the year. The short period of time in which neutral mentions exceeded positive mentions corresponds to the weeks of February and March 2021 in which AstraZeneca and Pfizer vaccines were introduced in the national campaign.

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The Janssen vaccine was approved for emergency use on March 21, 2021, and definitively registered by ANVISA on April 5, 2022. It is a vaccine that uses adenovirus vectors in its technology and has been approved for use in individuals from the age of 18. Regarding the number of doses for immunization, it is a single-dose vaccine, with a booster dose at least 2 months after primary vaccination[19]. In 2021, Janssen offered 38 million doses to the Ministry of Health, and its distribution and application by MS began only in June[10].

Despite this, neutral sentiments predominated during the 12 months evaluated. In the weeks leading up to its initial approval, positive sentiments were the second most identified type of feeling, although in a substantially lower proportion when compared to neutral feeling. However, from the beginning of its use at the national level, neutral and negative sentiments were more observed until the end of the screening.

Although it was disclosed as a single-dose vaccine, which could positively influence people's adherence, Janssen's vaccine was related to news about possible side effect characterized by the development of blood clots[25]. Considering that the dissemination of news with negative potential about vaccines that have been tested can generate a decrease in their adherence, this factor may be directly related to the neutral feeling expressed in the 12 months of the search. Similar results can be seen in the study by Fernandes-de-Oliveira et al (2023), in which the Janssen vaccine was the least mentioned in Instagram posts during the same period and was not linked to any negative emotional expression[3].

The AstraZeneca vaccine, which the registration granted by ANVISA took place on March 12, 2021, is used in the vaccination of people from 18 years of age. The vaccine uses recombinant adenovirus vector in its technology, and its immunization framework is based on two doses, the second being applied between 4 and 12 weeks after the first[21]. Although it has a dose administration scheme not very different from CoronaVac, the feeling most associated with the AstraZeneca vaccine was the feeling of neutral character. Two post peaks were observed, one during the month of January 2021 and another between the months of May and June 2021. In both moments there was a predominance of neutral sentiments.

Among the possible reasons that may have caused the postage peaks about the vaccine, it is worth mentioning ANVISA's approval for the import of 2 million doses and its emergency use, and these events occurred in January 2021. Later, between the months of May and July there were guidelines and suspensions of the AstraZeneca vaccine for use in pregnant women[21]. Such events may have affected the number of interactions, but do not present themselves as a reasonable explanation for the predominance of neutral interactions. The positive and negative sentiments related to this vaccine were similar throughout the period investigated, except in July 2021, when positive sentiments were more associated with the AstraZeneca vaccine than negative sentiments. This fact may be mainly related to the receipt of more than 1 million doses of the vaccine in Brazil, which took place in July 2021[21].

The Pfizer Vaccine received authorization from ANVISA on February 23, 2021 and thus began to be distributed and widely applied in the Brazilian population. Using messenger RNA technology, the vaccine should be applied in two doses for individuals from 5 years of age, respecting an interval greater than or equal to 21 days for the application of the second dose[21].

In May 2021, the Covid-19 Parliamentary Commission of Inquiry (CPI) in Brazil made public the information that Pfizer's first contacts with the Brazilian government to present its immunizer took place between May and June 2020. Millions of doses were offered for delivery in 2020, which did not happen because there was no government response - fact reported during the brazilian Parliamentary Inquiry Commission on the COVID-19 pandemic in 2021. This fact generated a great deal of commotion among Brazilian citizens, which is why the Pfizer vaccine is the immunizer with the highest number of tweets, with peaks in May and June.

In addition, about posts directed to the Pfizer vaccine, throughout the period analyzed, a high number of posts with positive and neutral sentiments were observed. Positive sentiments have become the most frequent since June 2021. This fact may be directly related to the distribution of more than 842,000 doses of this vaccine in the country in this month, as reported by the Pan American Health Organization. In the tact, what differentiates the engagement to Pfizer vaccine in this series are the negative reactions. Among all the vaccines analyzed, the Pfizer vaccine is the only one in which negative sentiments were consistently lower than positive and neutral sentiments throughout the period investigated.

Although they are vaccines with good results as to their effectiveness, political issues may be related to their non-acceptance. A study conducted by Figueiredo and Larson (2021), on the global intention of accepting vaccines showed that, in Brazil, in the speech of the former president of the republic "...we are not responsible for any side effects [of the vaccine]. If you become a crocodile, the problem is yours" your skepticism about the use of vaccines in the treatment of COVID-19 appears, which may have influenced a large part of the population to non-vaccine adherence[26].

According to the Brazilian Ministry of Health, the National Immunization Program is one of the largest in the world, offering 45 different immunobiologicals for the entire population, contemplating not only children, but also adolescents, adults, the elderly, pregnant women and indigenous peoples. However, despite Brazil having a well-established national immunization program, combined with a robust epidemiological surveillance system, delays in vaccinating the population and problems in distributing doses of the vaccine, combined with the circulation of fake news on social networks, contributed to the aggravation of the pandemic and demonstrated that the measures adopted were not sufficient to guarantee an effective response to the crisis[27]. In view of this, there is concern that scientific disinformation in social media may affect campaigns that have existed since the sixties[28].

It is important to note that this study is not without its limitations regarding sample representativeness. Obtaining samples appropriate to the distribution of the Brazilian population was challenging. Because X/Twitter does not allow filtering posts by geographic region, it was difficult to capture the real panorama of vaccine distribution in Brazil, particularly since some vaccines were predominantly available in specific areas. In addition, the data collection tool imposes limits on the number of searchable terms, restricting the retrieval of all potentially relevant tweets for sentiment analysis.

The decision not to apply stop-words removal or stemming may have affected the semantic precision of the analysis, while the sentiment classification model cannot detect irony or sarcasm, forms of expression frequently used on social media that can alter the intended polarity of messages. Moreover, the manual annotation relied on a curated set of 5,000 tweets, which, although carefully evaluated by two independent raters and resolved by consensus, may not capture the full variability of discourse present in the larger dataset.

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## Conclusion

The sentiment analysis performed from data obtained on X (former Twitter) serves as a tool to track sentiments regarding vaccination against COVID-19.The results obtained in this study from tweets show that most of the sentiments obtained for all vaccines were of a neutral character, however it was also possible to observe that the Coronavac vaccine developed in Brazil for emergency use in the COVID-19 pandemic, despite the negative publicity, was widely accepted by the population having most of the sentiments expressed in a positive way if considered with the data of the other vaccines. This data is very important mainly due to the numerous debates against this vaccine on social networks. Moreover, the results provide valuable insights that can inform public health strategies and support the formulation of more effective vaccination policies.

**CRediT Statement:**

MTFN, MJMS and LGS did conceptualization, methodology, investigation, formal analysis, data curation, writing, review and editing. A.R.M and D.P.L.J did conceptualization, methodology, investigation, formal analysis, data curation, supervision. A.D.O.F did conceptualization, methodology, investigation, formal analysis, data curation, supervision, project administration. All authors approved the version to be submitted.

All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

Not applicable.

**Availability of data and material**

Not applicable.

**Conflict interests**

The authors declare that they have no conflict interests.

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