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Comparison of Chemical, Biological, Physical and Electrical Properties between Commercial Ultrasound Gel and *Aloe vera* Gel

Comparação das Propriedades Químicas, Biológicas, Físicas e Elétrica entre o Gel Comercial para Ultrassom e o Gel de *Aloe vera*

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ABSTRACT

Ultrasound is an imaging diagnostic method that uses mechanical waves and requires acoustic coupling gel for the efficient transmission of ultrasonic waves. This study investigated *Aloe vera* gel as an alternative to the commercial gel used in ultrasound exams. The chemical, biological, electrical, and physical aspects of both gels were analyzed using Fourier Transform Infrared Spectroscopy (FTIR), Energy Dispersive X-ray Spectroscopy (EDS), cytotoxicity assays, and conductivity tests. The *Aloe vera* gel contained carbon, oxygen, magnesium, calcium, and phosphorus, while the commercial gel contained only carbon and oxygen. *Aloe vera* was found to be safe for biological tissues, with performance equivalent to or superior to the commercial gel in ultrasound exams. This can be attributed to its lower electrical resistance and higher quantity of free ions, which reduced impedance between the transducer and the skin, facilitating the propagation of ultrasonic waves. Thus, *Aloe vera* gel emerges as a promising and viable alternative for ultrasound, offering biocompatibility, technical performance, and safety.

Keywords: *Aloe vera*; Gel; Ultrasound; Biocompatibility.

RESUMO

A ecografia é um método de diagnóstico por imagem que utiliza ondas mecânicas e requer gel de acoplamento acústico para a transmissão eficiente das ondas ultrassônicas. Este estudo investigou o gel de *Aloe vera* como uma alternativa ao gel comercial usado em exames ecográficos. Foram analisados aspectos químicos, biológicos, elétricos e físicos dos dois géis, utilizando Espectroscopia na Região do Infravermelho com Transformada de Fourier (FTIR), Espectroscopia por Energia Dispersiva de Raios X (EDS), ensaios de citotoxicidade e testes de condutividade. O gel de *Aloe vera* apresentou carbono, oxigênio, magnésio, cálcio e fósforo, enquanto o gel comercial continha apenas carbono e oxigênio. *Aloe vera* mostrou-se seguro para tecidos biológicos, com desempenho equivalente ou superior ao gel comercial em exames de ultrassonografia. Isso pode ser atribuído à sua menor resistência elétrica e maior quantidade de íons livres, que reduziram a impedância entre o transdutor e a pele, facilitando a propagação das ondas ultrassônicas. Assim, o gel de *Aloe vera* surge como uma alternativa promissora e viável para ultrassonografia, oferecendo biocompatibilidade, desempenho técnico e segurança.

Palavras-chave: *Aloe vera*; Gel; Ecografia; Biocompatibilidade.

INTRODUCTION

Ultrasound, also known as sonography, is a diagnostic imaging technique widely used in medicine due to its ability to provide detailed images of internal tissues and organs without the need for invasive procedures (ENSMINGER; BOND, 2024). Since its development, which dates back to the 18th century with the discovery of the piezoelectric effect by the Curie brothers, ultrasound has evolved significantly, becoming an essential tool in medical practice. Using high-frequency sound waves, ultrasound allows the visualization of internal structures of the human body in real time, offering a safe and effective method for the diagnosis of various clinical conditions (OWUSU *et al.*, 2023).

The technological evolution of ultrasound equipment, particularly with regard to the development of piezoelectric transducers, has been crucial to the accuracy and reliability of ultrasound examinations. These transducers convert electrical energy into sound waves and vice versa, allowing the creation of two- and three-dimensional images from the echoes reflected by the internal structures of the body. The application of ultrasound extends across several medical specialties, such as cardiology, obstetrics, and radiology, and stands out for its accessibility, low cost, and safety, since it does not use ionizing radiation (ZHAO *et al.*, 2023).

An essential component for performing ultrasound examinations is the acoustic coupling gel. This gel is applied to the surface of the patient's skin to eliminate the air interface between the transducer and the skin, allowing efficient transmission of ultrasonic waves. The choice of material for the formulation of this gel is essential, as it must have specific properties that guarantee image quality, in addition to being safe and comfortable for the patient (AFZAL, 2022; AFZAL, S *et al.*, 2022; GAO *et al.*, 2023).

Gel quality can vary, influencing the effectiveness of ultrasonic wave transmission. Low-quality gels may not provide good acoustic conductivity, resulting in lower quality images, which may compromise diagnostic accuracy (BOMBARDA *et al.*, 2021). A possible alternative is the use of *Aloe vera* gel, a natural product with moisturizing and hygroscopic properties. These characteristics allow the gel to remain in the applied area for longer, reducing the need for replacement during the ultrasound examination and potentially improving the quality of the images, in addition to offering efficient and constant acoustic conductivity (AFZAL, S *et al.*, 2022; BOATENG, 2023).

Aloe vera is a plant known for its therapeutic properties, including anti-inflammatory, healing and moisturizing effects, which makes it suitable for topical application (JADHAV *et al.*, 2020). In addition to its medicinal properties, *Aloe vera* gel is biodegradable, low cost and can be a viable option to replace synthetic gels used in ultrasound examinations (SALEEM *et al.*, 2022).

This study aimed to investigate the chemical, biological, electrical and physical properties of *Aloe vera* gel, evaluating its effectiveness as an acoustic coupling gel in ultrasound examinations. In addition, its performance was compared with a commercial gel, with a view to promoting a sustainable and beneficial alternative for clinical practice.

MATERIALS E METHODS

Commercial ultrasound gel and *Aloe vera* gel were used to conduct this research. The commercial gel used to perform ultrasound was purchased at a local store, net weight of 250 grams, registered with Anvisa, for daily use in diagnostic imaging services, including at the Imaging Training Center/CETRIM.

The *Aloe vera* gel at a concentration of 1% (m/v) was obtained from the natural vegan powder of Herbia Ayurvedic, dissolved in distilled water and stored in a plastic tube-type container previously sterilized before use.

The samples of the commercial ultrasound gel and *Aloe vera* gel were characterized by Fourier Transform Infrared Spectroscopy (FTIR), Energy Dispersive X-ray Spectroscopy (EDS), Cytotoxicity, conductivity, electrical resistance and Ultrasound to analyze the possible differences between the images obtained with the two types of gels used.

The samples were sent for imaging examination using a General Electric (GE) Volussom ultrasound device, which was adjusted to assess abdominal examinations using the same parameters as the equipment for use with the two gel samples.

The images were obtained of the abdominal anatomical structures in the following sequence: left lobe of the liver, right lobe of the liver, right kidney, left kidney, spleen and bladder; using the commercial gel and then *Aloe vera* gel, to obtain a pictographic test and subsequent comparison of the captured images. The ultrasound images were obtained from tests carried out by the researcher himself (OGSN).

CHARACTERIZATIONS

Chemical Analysis

The test using the Fourier Transform Infrared Spectroscopy (FTIR) technique was performed at room temperature in a Perkin Elmer Spectrum 400 equipment, using the scanning range of 4000 to 650 cm-1. The commercial sample was dehydrated in an oven at 37º C for 72 h. The *Aloe vera* gel was prepared as purchased, in powder form. For the Energy Dispersive X-ray Spectroscopy (EDS) analyses, a detector installed in the vacuum chamber of the Scanning Electron Microscope (SEM), Phenon TM Pro X, was used.

Biological Analysis

In this study, the NCTC clone 929 (L-929) cell line was used as recommended by EN ISO 10993-5:2009. The cells were cultured in RPMI 1640 medium supplemented with 10% fetal bovine serum and 1% antibiotic-antimycotic, under aseptic conditions. The culture was incubated in a humidified atmosphere with 5% CO_2 at 37°C. After verifying the absence of mycoplasma contamination, the cells in exponential growth phase were trypsinized and counted, and then distributed in microplates for the cell viability assay using the MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) method, following the guidelines of EN ISO 10993-5:2009 and EN ISO 10993-

12:2012 standards. The plates were read in a spectrophotometer at 570 nm with a 650 nm reference filter.

Physical Analysis

The ultrasound examination was performed on a GE VOLUSON ultrasound device. At this stage, both types of gels were used to verify a possible difference in the quality of the images obtained.

Electrical Analysis

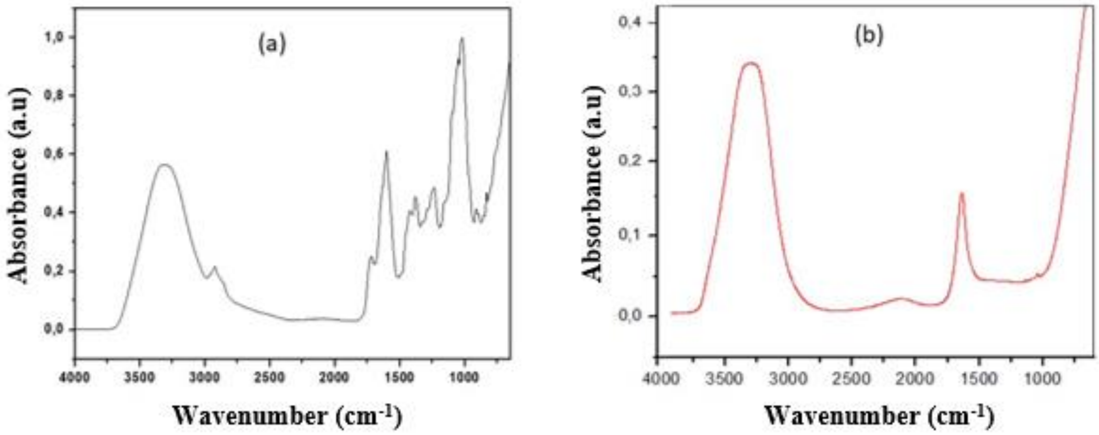
Conductivity tests and ultrasound were used to physically evaluate the gels. In order to verify the resistance measurements of the samples, the data acquisition equipment, model “Mainframe and data acquisition control modules 34970A" from Agilent Keysight Technologies, was used. To determine the resistance measurements of the commercial gel and *Aloe vera* gel, the electrodes were immersed in the samples and positioned at a distance of approximately 1 cm from each other, taking the measurement for a period of 5 minutes under ambient conditions. The results were obtained in triplicate.

RESULTS AND DISCUSSION

The infrared spectra illustrated in Figure 1 were obtained from samples of *Aloe vera* gel (a) and commercial gel (b). In the spectrum of *Aloe vera*, a peak is observed at around 3334 cm-1 corresponding to the free O-H functional group, at 1652 corresponding to the axial deformation of C=O, and at around 1070 corresponding to the axial deformation of C-O-C. These results are in agreement with CHISMIRINA *et al.* (2024) who formulated and analyzed a gel containing 10% *Aloe vera* for the treatment of periodontal diseases.

The absorbance peaks around 2920, 1420, 1370 cm-1 corroborate the *Aloe vera* powder spectrum obtained by BAJER *et al.* (2020), who explored the combination of starch, chitosan and *Aloe vera* for the development of new biocomposite materials with potential for applications in biodegradable packaging.

Figure 1 - Spectra of *Aloe vera* gels (a) and commercial gel (b).



Source: Research data (2024).

Many of the observed peaks refer to Acemannan, which is the main polymer present in *Aloe vera* gel, a polymer with a structural organization (at the molecular level). Many of the beneficial health effects provided by *Aloe vera* are also provided by the presence of this polymer in its composition, such as immunomodulatory, antimicrobial and healing properties (DARZI *et al.*, 2021).

For both samples, a peak is observed around 3650–3600 cm^{-1}, which is characteristic of the stretching of the free O-H functional group. In this case, the formation of hydrogen bonds can be observed due to the broadening of the peak and its shift to the right around 3500–3200 cm^{-1}. The presence of O-H from alcohols and phenols is confirmed by the C-O found in the low intensity peak near 1300–1000 cm^{-1}. Therefore, this peak is due to primary alcohols at a wavenumber of approximately 1050 cm^{-1}. (BAJER *et al.*, 2020).

According to AHLUWALIA (2023) the presence of O-H in alcohols and phenols is confirmed by the C-O found in the low intensity peak near 1300 – 1000 cm^{-1}. Therefore, this peak is due to primary alcohols at a wave number of approximately 1050 cm^{-1}.

Table 2 shows the EDS results for the commercial gel and *Aloe vera* samples. Note that the commercial gel sample contains carbon and oxygen atoms. For *Aloe vera*, the presence of carbon, oxygen, magnesium, calcium and phosphorus atoms is observed. The presence of carbon and oxygen atoms is largely related to the Acemannam polymer, the main constituent of *Aloe vera* gel (LIMA *et al.*, 2022).

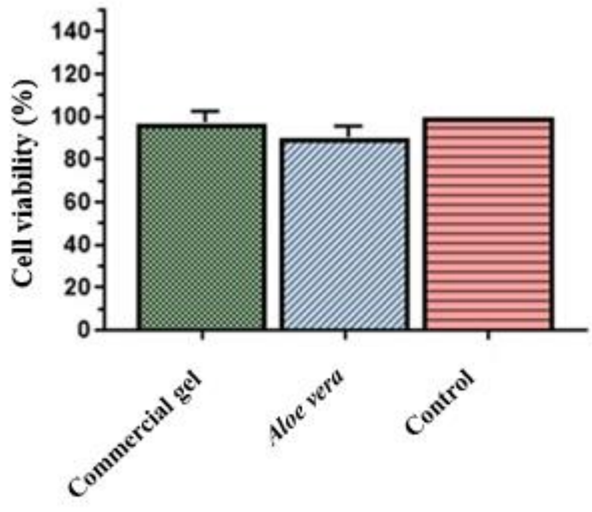
Table 2 – Chemical composition of *Aloe vera* gels and the ultrasound commercial.

Chemical element	*Aloe vera* (%)	Commercial ultrasound gel (%)
Carbon	45.01	66.67
Oxygen	47.00	33.33
Magnesium	4.80	--
Calcium	2.02	--
Phosphorus	1.17	--

Source: Research data (2024).

The EDS results justify the presence of the functional groups observed in the FTIR and may also be related, due to the free ions of magnesium, calcium and phosphorus. Figure 2 shows the results obtained in the cytotoxicity test of the gel samples.

Figure 2 – Cell viability of commercial ultrasound gel and *Aloe vera* gel.



Source: Research data (2024).

It can be observed that all samples presented cell viability greater than 90%, according to NBR ISO 10993-5:2009 (2009) cell viability greater than or equal to 70% indicates a non-cytotoxic material, which proves that none of the gels analyzed in this work were cytotoxic. The negative control was used to compare the membranes. The negative control (NC) is equivalent to 100% viability with the cells being maintained in culture medium (RPMI-16400). The cell viability results of the *Aloe vera* gel corroborate the work of ALLAFCHIAN *et al.* (2022) which demonstrated the contribution of *Aloe vera* gel to the viability of L929 cells in hybrid nanofibrous 3D *scaffolds* containing *Aloe vera* (AV), polyvinyl alcohol (PVA) and tetracycline hydrochloride (TCH) by electrospinning.

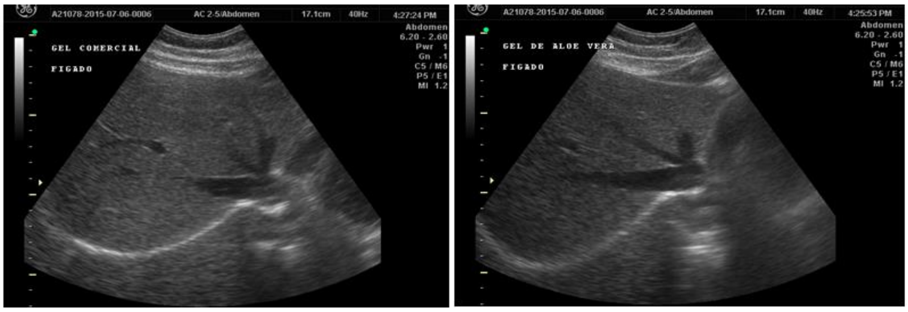
When you look at an ultrasound image, you are seeing the spatial distribution of echo-generating structures along the direction of sound propagation and along the scanning direction of the ultrasonic beam (KREMKAU, 2019). The characteristics of the ultrasonic beam, the medium and the image processing define the appearance of objects on ultrasound (BREYER, 2020). In this way, it is possible to study organs and anatomical structures according to their appearance, which will technically be described based on echogenicity and echotexture (CURRY; PRINCE, 2020).

Structures that do not generate echoes are called anechoic, structures that generate few echoes are called hypoechoic, and structures that generate intense echoes are called hyperechoic (OGLAT *et al.*, 2020). Therefore, anechoic structures mean that ultrasound passes more easily through these structures and returns little to the device, generating dark images on ultrasound, for example, there are liquids and, therefore, a full bladder is an anechoic or hypoechoic anatomical structure (MATTOON *et al.*, 2020). On the other hand, hyperechoic structures give rise to clear images as they reflect a large part of the waves emitted by the ultrasound probe, such as calcification foci (SENNOGA, 2020).

Echotexture refers to the similarity between brightness intensities of image-forming elements (pixels) (ZHI *et al.*, 2021). The more similar they are in a given organ, the more homogeneous the echotexture is (FOGAÇA *et al.*, 2019). However, the less similar the brightness intensities between the pixels, the more heterogeneous the echotexture of the evaluated organ will be (VARA *et al.*, 2020). Echotexture roughly translates the homogeneity or heterogeneity of the tissues studied (THIEME, 2022). For example, the liver and spleen are organs with homogeneous echotexture. Echotexture changes can be observed in several diseases, such as liver cirrhosis (ROSSELLI *et al.*, 2023).

Echotexture and echogenicity were the basis for the evaluation and comparison of images taken in the same anatomical structures, using the same parameters in detail and on the same ultrasound device, in an examination with image acquisitions using commercial gel and then using *Aloe vera* gel as observed in Figure 3, to visualize the liver.

Figure 3 – Ultrasound images taken using commercial gel and *Aloe vera* gel to visualize the liver. Highlight the confluence of the right hepatic vein (RHV), middle hepatic vein (MHV) and left hepatic vein (LEV) for drainage into the inferior vena cava (IVC).

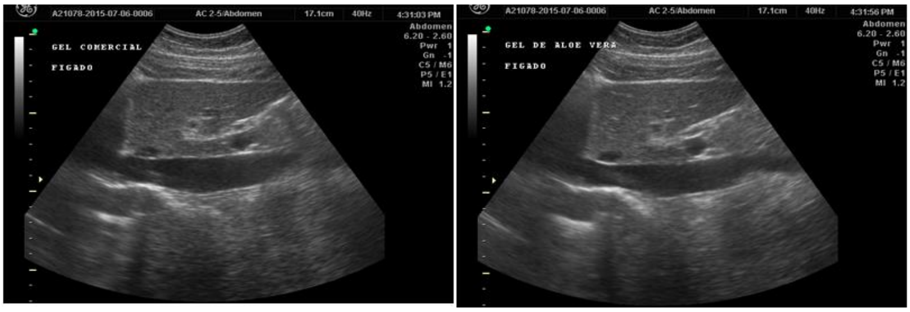


Source: Research data (2024).

The normal liver presents intermediate echogenicity (serving as a reference for the other abdominal organs) and homogeneous echotexture. Within the liver parenchyma, small hyperechoic spots can be observed distributed regularly, corresponding to the portal triads (region containing bile ducts, hepatic arterioles and subsegments of the portal vein). Observe in the image acquired with a transducer in the oblique transverse position, the liver being demonstrated with three confluent anechoic tubular structures amid the liver parenchyma, in detail the confluence of the right hepatic vein (RHV), middle hepatic vein (MHV) and left hepatic vein (LHEV) for drainage into the inferior vena cava (IVC) (ILIESCU, 2020).

The similarity between the images using the commercial gel and the *Aloe vera* gel can be seen, as shown in the caption on the images, showing the same details of the organ in question, regarding echogenicity and echotexture. Figure 4 shows the left lobe (LE) of the liver in a longitudinal section at the level of the inferior vena cava, an ultrasound image used as a protocol for abdominal examinations. This is a longitudinal image obtained in the midsternal line, often performed by ultrasound technicians to demonstrate and measure the left lobe of the liver. The richness of the details can be seen when viewing the images obtained with the commercial gel and the *Aloe vera* gel, from the superficial layers of the skin, close to the transducer, to deeper layers where the inferior vena cava (IVC) is evident, an anechogenic tubular structure located adjacent to the liver.

Figure 4 – Ultrasound images taken using commercial gel and *Aloe vera* gel to visualize the liver, LE = left lobe of the liver; VCI = inferior vena cava.



Source: Research data (2024).

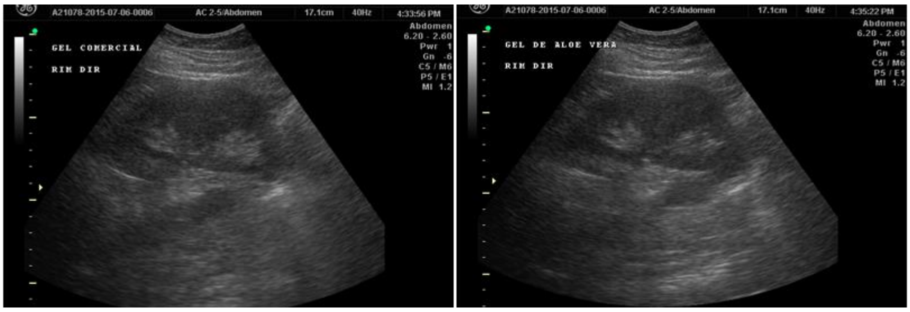
The spleen is the largest lymphatic organ in the human body, interposed in the bloodstream, located posteriorly in the upper left quadrant of the abdomen (NGUYEN *et al.*, 2020). On ultrasound, the spleen has a solid appearance with a highly homogeneous echotexture, and it is not possible to differentiate between its histological components (DAVIDSON, 2022). Its echogenicity is slightly lower than that of the liver and considerably higher than that of the kidneys (WU *et al.*, 2021) as illustrated in Figure 5.

Figure 5 – Comparative images of the spleen using the commercial gel and *Aloe vera* gel.

Source: Research data (2024).

The images acquired with commercial gel and *Aloe vera* gel allow for a complete assessment of the echotexture and echogenicity of the spleen, as well as analysis of morphological changes, taking the necessary measurements to calculate the dimensions of the organ and making comparisons with the other abdominal viscera. Figure 6 shows the images of the right kidney obtained using the commercial gel and *Aloe vera* gel, respectively.

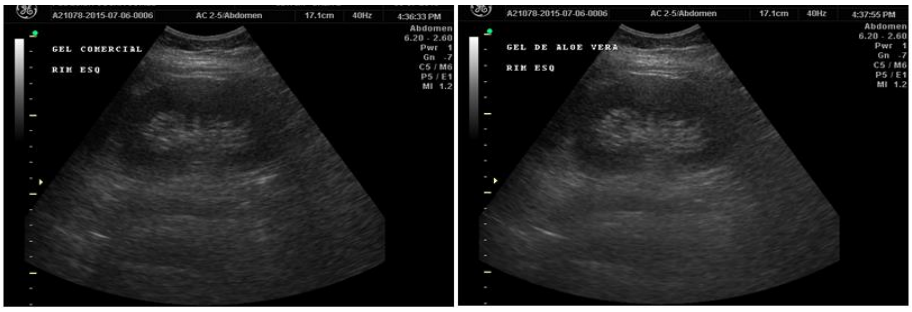
Figure 6 – Ultrasound images of the right kidney acquired using commercial gel and *Aloe vera* gel, note in the upper right quadrant of the image that the device adjustment parameters in both images are strictly the same.



Source: Research data (2024).

Figure 7 shows the images of the left kidney obtained using the commercial gel and *Aloe vera* gel respectively.

Figure 7 – Observe comparative images of the left kidney using the commercial gel and *Aloe vera* gel.



Source: Research data (2024).

The kidneys are encapsulated organs with a roughly oval shape and a complex internal architecture, which can be assessed by ultrasound due to the difference in internal echogenicity. The renal cortex is located on the periphery with hypoechogenicity and the medullary layer is more central, where the renal sinus is located, presenting hyperechogenicity as seen in the images of the right and left kidneys (COCHLIN, 2020; SINGLA, 2023). Note that the images acquired with commercial gel and *Aloe vera* gel are quite similar in oblique longitudinal sections. Note the various differences in echogenicity in the images, delimiting the edges of the organ and identifying the medullary layer and the renal cortex.

Ultrasound evaluation of the kidneys is extremely important in the evaluation of diffuse and focal nephropathies, and faithfully reflects the macroscopic anatomical details. Observing the details of the image in longitudinal sections of the left kidney shows great uniformity between the images obtained with the commercial gel and *Aloe vera* gel, analyzing everything from the limits of the organs to their internal architecture.

In ultrasound, the bladder is best evaluated when moderately distended, appearing as an anechoic structure with variable morphology, depending on the degree of distension (DAVIDSON, 2022). Figure 8 shows similar images using the commercial gel and *Aloe vera* gel, in cross-sections of the lower abdomen and pelvis, the anechogenicity of the bladder is well evaluated, as well as the hyperechogenic layered appearance of the bladder wall.

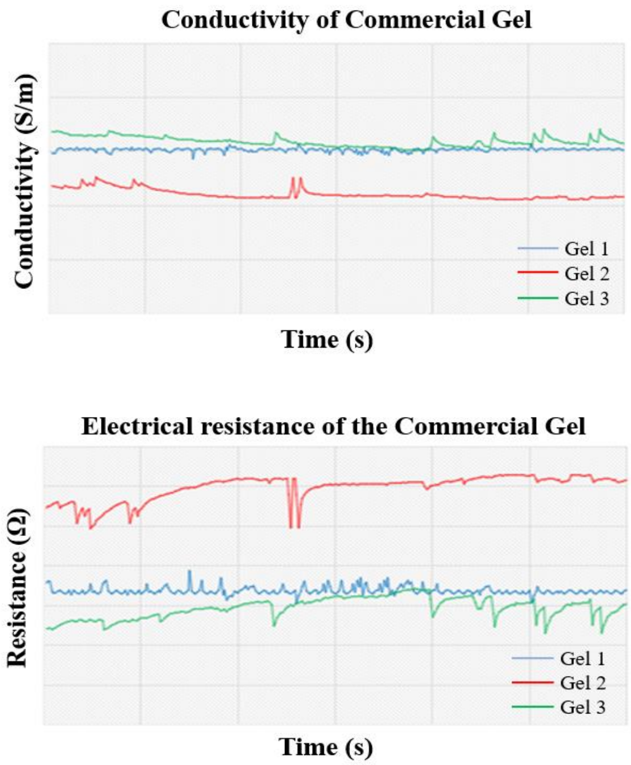
Figure 8 – Comparative image of the bladder acquired with commercial gel and *Aloe vera* gel.

Source: Research data (2024).

Figure 9 illustrates the conductivity of the commercial ultrasound gel and the *Aloe vera* gel. It can be seen that the conductivity results of the *Aloe vera* gel presented higher values than the results of the commercial gel. This may be related to the amount of free ions in the A*loe vera* gel and also to the lower viscosity. These results corroborate those obtained in the EDS test, which demonstrated a greater quantity of different chemical elements.

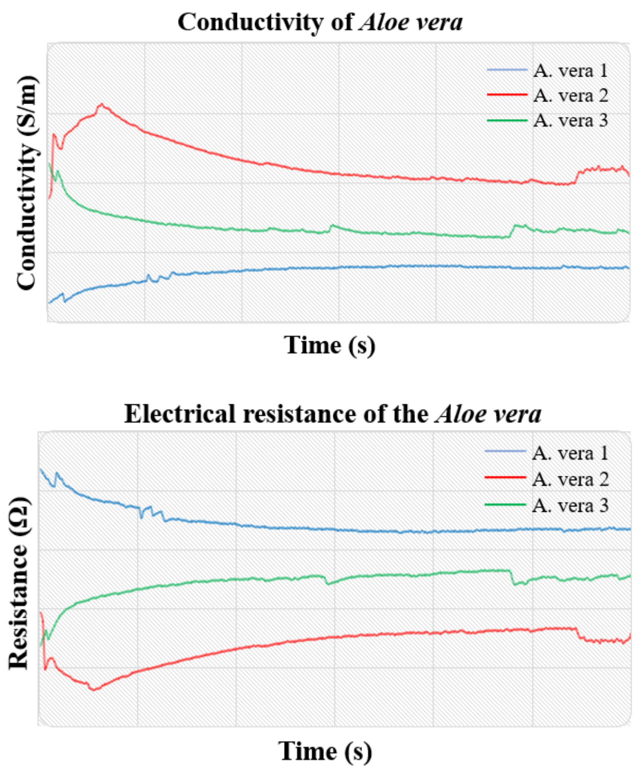
Regarding the results obtained for conductivity, resistance and in the echogram, it can be confirmed that the echograms had better quality due to the greater conductivity and lower resistance of the *Aloe vera* gel sample when compared to the commercial ultrasound gel (Figures 9 and 10), corroborating with AFZAL, SADIA *et al.* (2022) who formulated an economical alternative to commercial ultrasound gel, which is expensive and usually imported from other countries, from natural ingredients. In the resistance results of the commercial gel and *Aloe vera* gel, results were inversely proportional to those of conductivity. This occurs because this value was determined by the inverse of the resistance.

Figure 9 – Conductivity and resistance results of the commercial gel.



Source: Research data (2024).

Figura 10 – Resultado de condutividade e resistência do gel de *Aloe vera*.



Source: Research data (2024).

CONCLUSION

Aloe vera gel, when used for imaging purposes, presented results equal to or better than those obtained with commercial gel. The lower resistance offered by *Aloe vera* gel, and consequently greater conductivity, probably occurred due to the amount of free ions, allowing the transducer's impedance to be reduced in relation to the skin, promoting the propagation of ultrasound from the transducer to the organs being evaluated. Based on the results obtained in the Fourier Transform Infrared Spectroscopy, Energy Dispersive X-ray Spectroscopy and Ultrasound Examination tests, it can be concluded that the materials present similar characteristics, indicating that *Aloe vera* gel can be used in ultrasound examinations.

REFERENCES

AFZAL, S. Preparation and evaluation of polymer-based ultrasound gel and its application in ultrasonography. **Gels**, 8, n. 1, p. 42, 2022.

AFZAL, S.; ZAHID, M.; NIMRA, S.; FATIMA, Z.; SHAKIR, H. F.; REHAN, Z. Ultrasound hydrogel: A review on materials and method. **Mod. Polym. Chem. Mater**, 1, n. 2, 2022.

AFZAL, S.; ZAHID, M.; REHAN, Z. A.; SHAKIR, H. M. F.; JAVED, H.; ALJOHANI, M. M. H.; MUSTAFA, S. K.; AHMAD, M.; HASSAN, M. M. Preparation and Evaluation of Polymer-Based Ultrasound Gel and Its Application in Ultrasonography. 8, n. 1, p. 42, 2022.

AHLUWALIA, V. Infrared Spectroscopy. *In*: **Instrumental Methods of Chemical Analysis**: Springer, 2023. p. 179-231.

ALLAFCHIAN, A.; FATHI, M.; JALALI, S. A. H. Design of polysaccharidic Aloe vera gel incorporated PVA/tetracycline electrospun cell culture scaffolds for biomedical applications. **Nanotechnology**, 33, n. 29, p. 295101, 2022.

BAJER, D.; JANCZAK, K.; BAJER, K. Novel starch/chitosan/aloe vera composites as promising biopackaging materials. **Journal of Polymers the Environment**, 28, n. 3, p. 1021-1039, 2020.

BOATENG, I. D. Thermal and nonthermal assisted drying of fruits and vegetables. Underlying principles and role in physicochemical properties and product quality. **Food Engineering Reviews**, 15, n. 1, p. 113-155, 2023.

BOMBARDA, D.; VITETTA, G. M.; FERRANTE, G. Rail diagnostics based on ultrasonic guided waves: An overview. **Applied Sciences**, 11, n. 3, p. 1071, 2021.

BREYER, B. Basic physics of ultrasound. *In*: **Ultrasound and Infertility**: CRC Press, 2020. p. 1-21.

CHISMIRINA, S.; CANDRA, G. I.; ANDAYANI, R.; HAKIM, R. F.; AFRINA, A.; PUTRI, C. F.; OKTAVIARY, A.; NASUTION, A. I.; GANI, B. A. Study of formulation and FTIR Analysis of Aloe Vera Gel for Periodontal Disease Therapy. **Journal of Community Dentistry Dental Research**, 2, n. 1, p. 7-13, 2024.

COCHLIN, D. L. Urinary tract. *In*: **Diagnostic Ultrasound, Second Edition**: CRC Press, 2020. p. 819-893.

CURRY, R.; PRINCE, M. **Sonography E-Book: Sonography E-Book**. Elsevier Health Sciences, 2020. 0323790801.

DARZI, S.; PAUL, K.; LEITAN, S.; WERKMEISTER, J. A.; MUKHERJEE, S. Immunobiology and application of aloe vera-based scaffolds in tissue engineering. **International journal of molecular sciences**, 22, n. 4, p. 1708, 2021.

DAVIDSON, N. J. Ultrasound of the Renal Tract. **Abdominal Ultrasound E-Book: Abdominal Ultrasound E-Book**, p. 185, 2022.

ENSMINGER, D.; BOND, L. J. **Ultrasonics: fundamentals, technologies, and applications**. CRC press, 2024. 1000994953.

FOGAÇA, J. L.; VETTORATO, M. C.; PUOLI-FILHO, J. N. P.; FERNANDES, M. A.; MACHADO, V. M. V. Grayscale histogram analysis to study the echogenicity and echotexture of the walls of the common carotid arteries of horses and mules. **Pesquisa Veterinária Brasileira**, 39, p. 221-229, 2019.

GAO, W.; CHEN, Y.; LIU, W. Research and optimum selection of coupling agent materials in ultrasonic measurement. **Journal of Materials Research Technology**, 26, p. 1006-1015, 2023.

ILIESCU, L. Liver Diseases: A Multidisciplinary Textbook. p. 459-471, 2020.

JADHAV, A. S.; PATIL, O. A.; KADAM, S. V.; BHUTKAR, M. A. Review on Aloe Vera is used in medicinal plant. **Asian Journal of Research in Pharmaceutical Science**, 10, n. 1, p. 26-30, 2020.

KREMKAU, F. W. **Sonography Principles and Instruments E-Book**. Elsevier Health Sciences, 2019. 0323597092.

LIMA, E. N. d. C.; MARTINS, G. L. B.; DIAZ, R. S.; SCHECHTER, M.; PIQUEIRA, J. R. C.; JUSTO, J. F. Effects of carbon nanomaterials and Aloe vera on melanomas—where are we? Recent updates. **Pharmaceutics**, 14, n. 10, p. 2004, 2022.

MATTOON, J. S.; NYLAND, T. J. S. A. D. U. M., 3rd ed.; MATTOON, J., Nyland, TG, Eds. Fundamentals of diagnostic ultrasound. p. 1-49, 2020.

NGUYEN, L.; ZHANG, L.; LIVER. Anatomy and Histology of Normal Liver and Spleen. **Diagnostic Pathology of Hematopoietic Disorders of Spleen**, p. 1-9, 2020.

OGLAT, A. A.; ALSHIPLI, M.; SAYAH, M. A.; AHMAD, M. S. Artifacts in diagnostic ultrasonography. : SAGE Publications Sage CA: Los Angeles, CA 2020.

OWUSU, F.; VENKATESAN, T. R.; NÜESCH, F. A.; NEGRI, R. M.; OPRIS, D. M. How to Make Elastomers Piezoelectric? **Advanced Materials Technologies**, 8, n. 15, p. 2300099, 2023.

ROSSELLI, M.; ROCCARINA, D.; GRGUREVIC, I. Ultrasound in Chronic Liver Disease. **Liver Ultrasound: From Basics to Advanced Applications**, p. 124-155, 2023.

SALEEM, A.; NAUREEN, I.; NAEEM, M.; MURAD, H. S.; MAQSOOD, S.; TASLEEM, G. Aloe vera gel effect on skin and pharmacological properties. **Scholars international journal of anatomy**

physiology, 5, n. 1, p. 1-8, 2022.

SENNOGA, C. A. Ultrasound imaging. *In*: **Bioengineering Innovative Solutions for Cancer**: Elsevier, 2020. p. 123-161.

SINGLA, R. K. **Quantitative kidney ultrasound from macroscale to microscale**. 2023. -, University of British Columbia.

THIEME, G. A. Clinical relevance of scattering. *In*: **Ultrasonic Scattering in Biological Tissues**: CRC Press, 2022. p. 19-51.

VARA, G.; RUSTICI, A.; SECHI, A.; MOSCONI, C.; LUCIDI, V.; GOLFIERI, R. Texture analysis on ultrasound: The effect of time gain compensation on histogram metrics and gray-level matrices. **Journal of medical physics**, 45, n. 4, p. 249-255, 2020.

WU, M.; SHARMA, P. G.; GRAJO, J. R. The echogenic liver: steatosis and beyond. **Ultrasound Quarterly**, 37, n. 4, p. 308-314, 2021.

ZHAO, Z.; SAIDING, Q.; CAI, Z.; CAI, M.; CUI, W. Ultrasound technology and biomaterials for precise drug therapy. **Materials Today Bio**, 63, p. 210-238, 2023.

ZHI, X.; CHEN, J.; XIE, F.; SUN, J.; HERTH, F. J. Diagnostic value of endobronchial ultrasound image features: A specialized review. **Endoscopic ultrasound**, 10, n. 1, p. 3-18, 2021.