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Organoleptic qualities of products derived from two ecotypes of tiger nut (Cyperus esculentus) cultivated in Niger.

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***Keywords*— tigernut tubers, processing, derivative products, organoleptic quality, Maradi, Niger.**

***Abstract*—** *Despite the development of tiger nut cultivation in Niger, the potential of its tubers remains underutilized. The present study was conducted in this context, with the aim of promoting these tubers in Niger. The study began with the collection of two ecotypes of tiger nuts in Tchadoua and Chadakori in the Maradi region. The ecotypes were then processed into flour, milk, and cookies at the Research Laboratory for Hygiene, Food Science, and Nutrition at the Faculty of Agronomy in Niamey. A panel of ten people evaluated the organoleptic quality of each product. The study concluded that there was a strong preference for products made from unsoaked large tiger nuts, particularly flour and milk. For the milk products, this preference was based on color (E4), taste (E12), smell (E10), and consistency (E2). The most popular products were the baked cookies and "dakoua" E1, which were made from 100% tiger nuts and accepted by the panelists. This study may therefore contribute to diversifying tiger nut products and developing the sector economically.*

I. INTRODUCTION

Cyperus esculentus L., commonly called the "sweet nut," is a perennial plant that grows from rhizomes and tubers. Cultivated species are often annuals. It belongs to the Cyperus genus of the Cyperaceae family and spreads entirely through underground tubers. It is also known by various names, such as yellow carbide, tiger nut, chufa, underground chestnut, marbale, underground walnut, ground almond, ginseng fruit, sweet pea, and "thiogon" (Sembé *et al.*, 2019 ; **Zhang** *et al.*, 2022). In Niger, tiger nut cultivation is the third most valuable export crop in terms of foreign exchange earnings after onions and cowpeas (GOMBO, 2005). It can contribute over 500 million CFA francs per year to small-scale producers' incomes (Aoua et *al.*, 2008). Although tiger nut cultivation is growing, there are few studies on this product (BORI, *et al.,2018*). Tiger nuts are one of the few tubers with a high fatty acid content (25.2 g per 100 g of raw tiger nuts) and are notable for their high fiber content (Haoua *et al.*, 2023). The skin of the tuber contains most of the insoluble fiber (11.2 g per 100 g of peeled tiger nut compared to 33 g per 100 g of unpeeled tiger nut). Tiger nuts also contain high-quality vegetable protein with essential amino acids, such as arginine, leucine, and lysine (Dupont, 2023). Tiger nuts are rich in vitamins E and C, as well as minerals and trace elements such as phosphorus, calcium, potassium, magnesium, iron, and zinc. They are a real source of energy, providing 549 kcal per 100 g of raw tiger nuts. In Niger, tiger nuts are used in

various forms in human food (cookies, candies, flour, milk, etc.) (Bori, *et al.,2018*). Like most tubers, tiger nuts help combat malnutrition thanks to their chemical composition, medicinal properties, and anti-inflammatory and anti-apoptotic effects (Ban-Koffi et al 2005; Yali Yu *et al.*, 2022) Traditional processing methods for tiger nut tubers include soaking and roasting (salted or sweetened), making biscuits called "dakoua" (flour mixed with sugar), and making a juice called "nono aya" (Bori, et *al.,2018,* Adjahossou *et al*., 2021). This study aims to evaluate the organoleptic quality and acceptability of tiger nut-derived products.

II. MATERIALS AND METHODS

2.1 Study Setting

Tigernuts were collected in the Maradi region, specifically in the Tchadoua and Chadakori municipalities, which are located in the Aguié and Guidan Roumdji departments, respectively (figure 1). The experimental site for processing tiger nut tubers is the Laboratory for Research in Hygiene, Food Science, and Nutrition (LARHSAN) at the Abdou Moumouni University Faculty of Agronomy in Niamey.

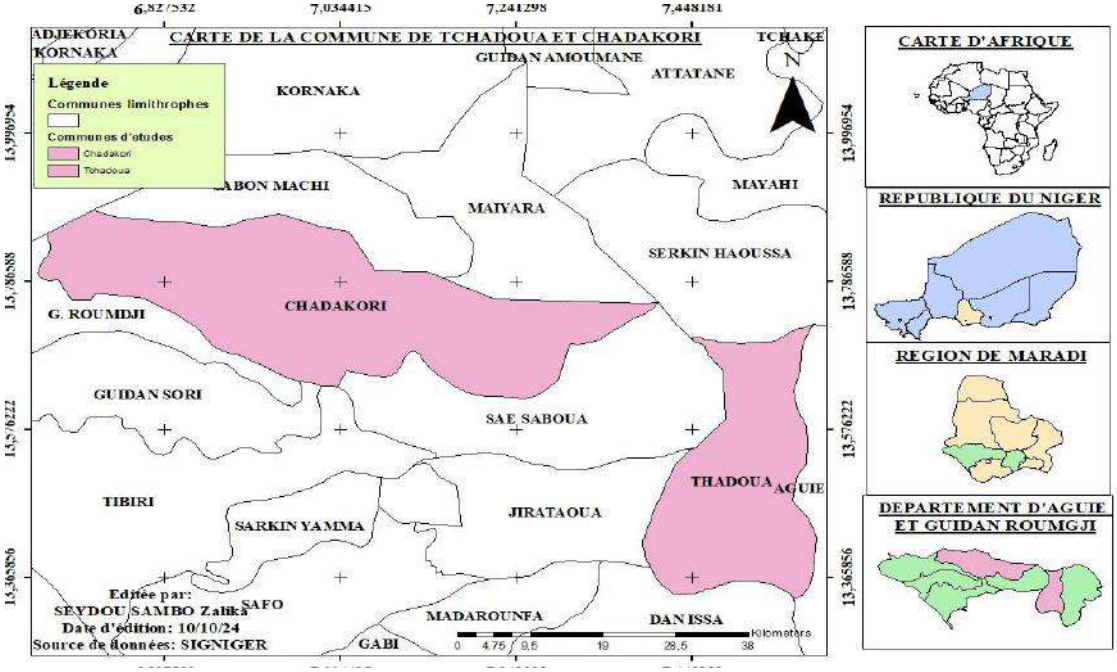


Fig.1: Map of the Tchadoua and Chadakori collection area

2.2 Plant Material

The plant material used in this study consists of products derived from large (GTN) and small (STN) tiger nuts produced in the laboratory, including tiger nut flour, cookies, dakoua, milk, and porridge (Figure 2).

2.3. Sensory Analysis Procedure and Data Processing

The sensory analysis was conducted at the Laboratory for Research in Food Hygiene and Nutrition (LARH-SAN). A tasting panel of ten people was selected at random for each tiger nut product based on the inclusion criterion of regularly consuming tiger nuts. The organoleptic testing of tiger nut products required the following equipment: - Small boxes with spoons for flour and porridge

- Small disposable cups for milk

- Plates for Dakoua and Cookies

- A glass of water for each taster to rinse their mouth

Data processing and percentage calculations were performed using Microsoft Excel software. Data processing and percentage calculations were performed using Microsoft Excel.

	Flours	Cookies	"Dakoua" Cookies	Milks	Boiled products
C Derivative products					

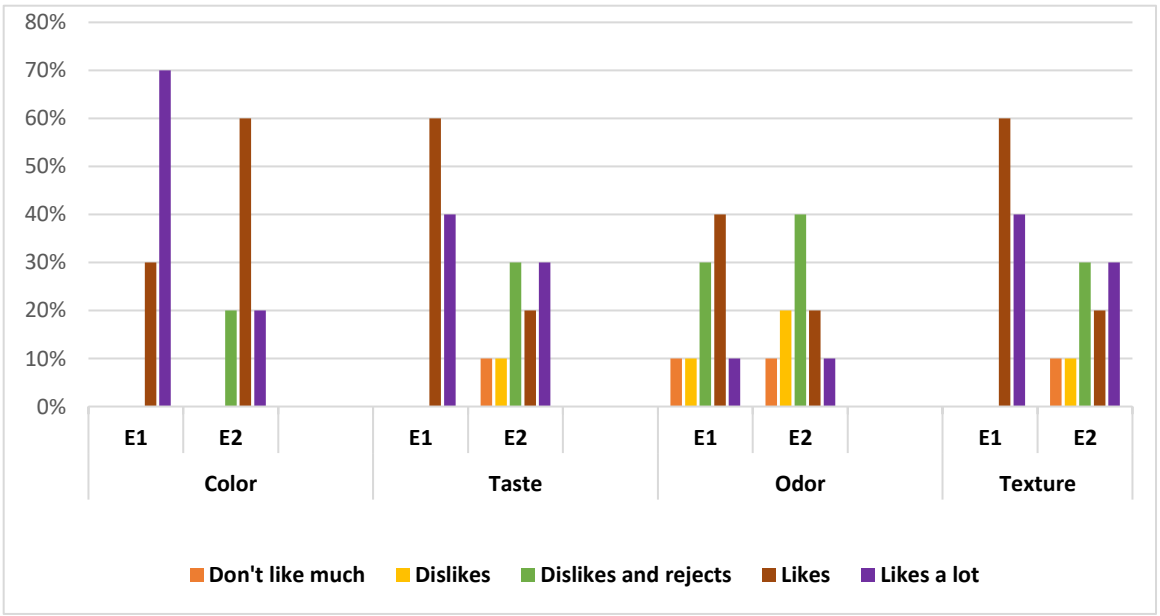
Fig.2: A. Small nut,B. Large nut, C. Derivative products studied

III. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Assessment of the Organoleptic Parameters of Tiger Nut Flours

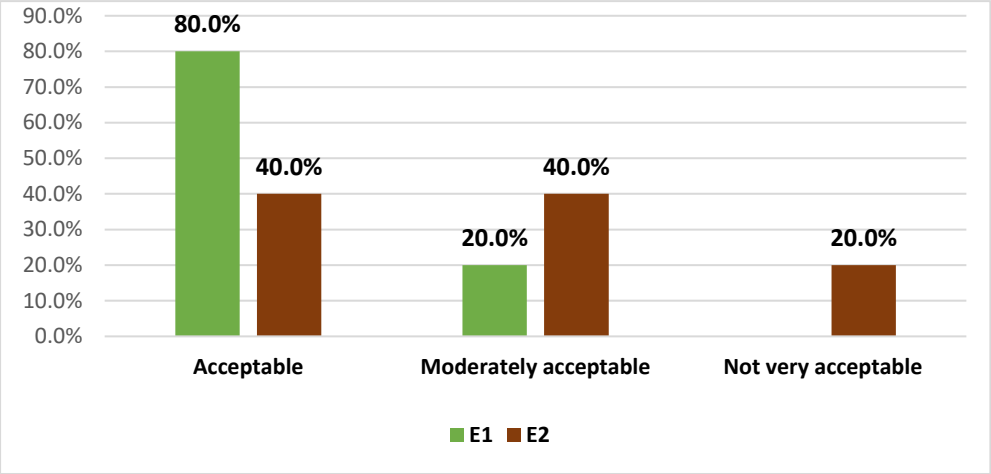
Figures 3 and 4 show the organoleptic test results and acceptability of flours from the two types of tiger nuts grown in Niger, respectively.



E1 is large tiger nut flour and E2 is small tiger nut flour.

Fig.3: the assessment of the organoleptic parameters of the flours from the two types of tiger nut.

The large and small tiger nut flours received a "Like very much" rating of 70% for color from the panelists. In terms of taste and texture, E1 received a higher rating (60%) by the panelists with the rating “Like” and finally, regarding the smell, 40% respectively for the ratings ‘Like’ and “Don't like and don't dislike” for samples E1 and E2.



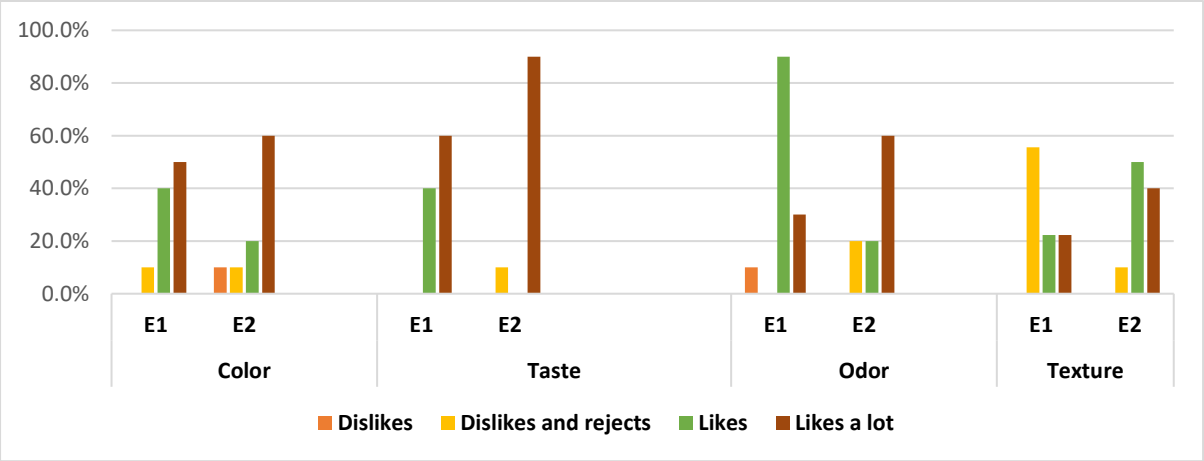
E1: Large tiger nut flour E2: Small tiger nut flour

Fig.4: acceptability of the flours from the two tiger nut ecotypes.

The analysis shows that 80% of tasters found E1 "acceptable," 40% found E2 "moderately acceptable," and 20% found E2 "unacceptable." Overall, the sensory analysis results show that large tiger nut flour is the most acceptable.

3.1.2. Assessment of the Organoleptic Parameters of Tiger Nut Cookies

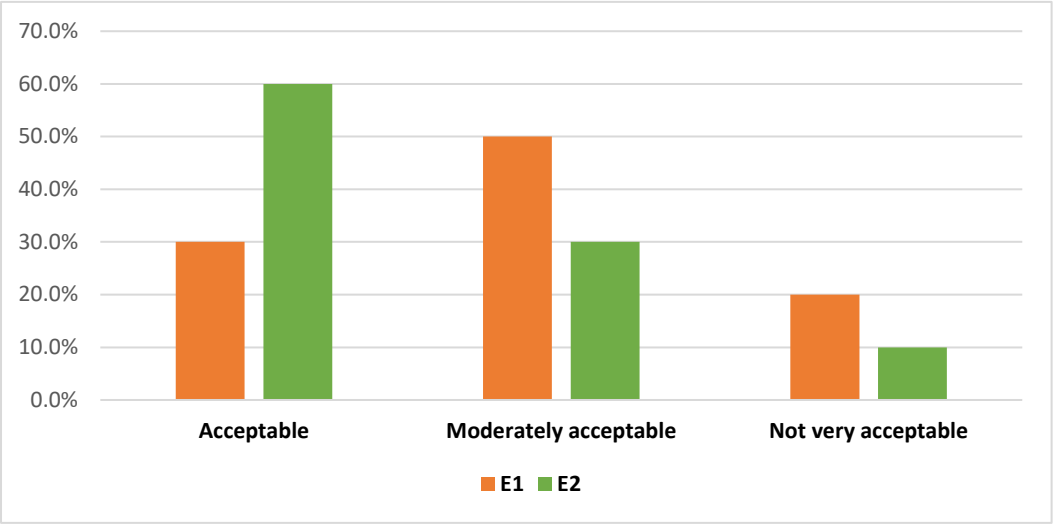
Figures 5 and 6 show the organoleptic test results relating to color, taste, smell, texture, and the acceptability of tiger nut Cookies fried in oil and baked in the oven.



E1: Oil-fried biscuit E2: Oven-baked biscuit

Fig.5: assessment of the color, taste, smell, and texture of tiger nut cookies.

Figure 5 shows that sample E2 was the most appreciated in terms of taste and color. Ninety percent of panelists chose the "like very much" option for taste, and 60% chose the same option for color. In terms of smell, 90% of the panelists preferred sample E1, and 60% "really liked" the smell of the baked cookies. However, 55.6% did not appreciate the texture of the oil-fried cookies.



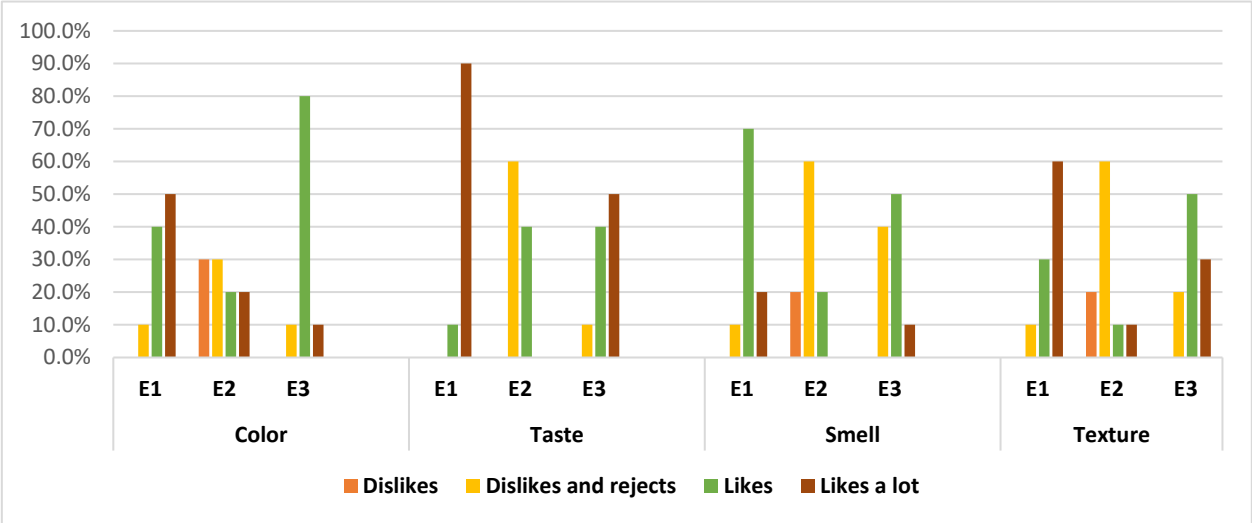
E1: Oil-fried biscuit. E2: Oven-baked biscuit.

Fig.6: Acceptability of the oil-fried and oven-baked cookies.

Analysis of Figure 6 shows that 60% of panelists rated cookie E2 as "acceptable," 50% rated cookies E1 as "acceptable," and 20% and 10% rated cookies E2 and E1 as "moderately acceptable" and "not very acceptable," respectively.

3.1.3. Assessment of the organoleptic parameters of the different "Dakoua" variants produced.

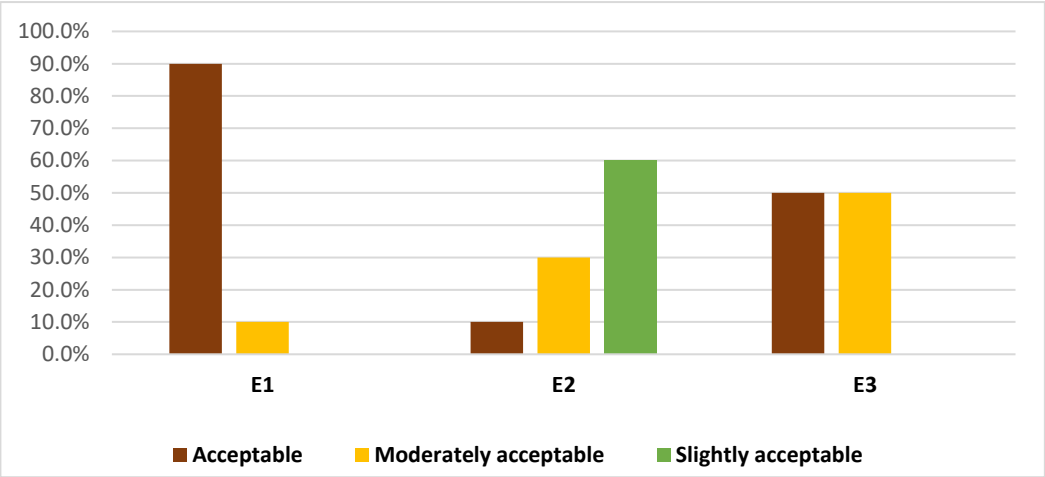
Figures 7 and 8 show the results relating to color, taste, smell, texture, and acceptability.



E1: 100% tiger nut "Dakoua"; E2: 85% tiger nut, 15% millet "Dakoua"; E3: "Dakoua" with 90% tiger nuts and 10% milk.

Fig.7: Assessment of the color, taste, smell, and texture of the different variants of "Dakoua."

The analysis shows that E3 was the most popular in terms of color, with 80% of panelists choosing the "like" option. In terms of taste and texture, 90% and 60% of panelists, respectively, chose the option "like very much" for E1 and E3, while 60% of panelists chose the option "don't like and don't reject" for E2. Panelists also preferred the smell of E1 and E3, with 70% and 50%, respectively, choosing "like." E1, made from 100% tiger nuts, was the most popular "Dakoua," while E2, made from a mixture of tiger nuts and millet, was the least popular.



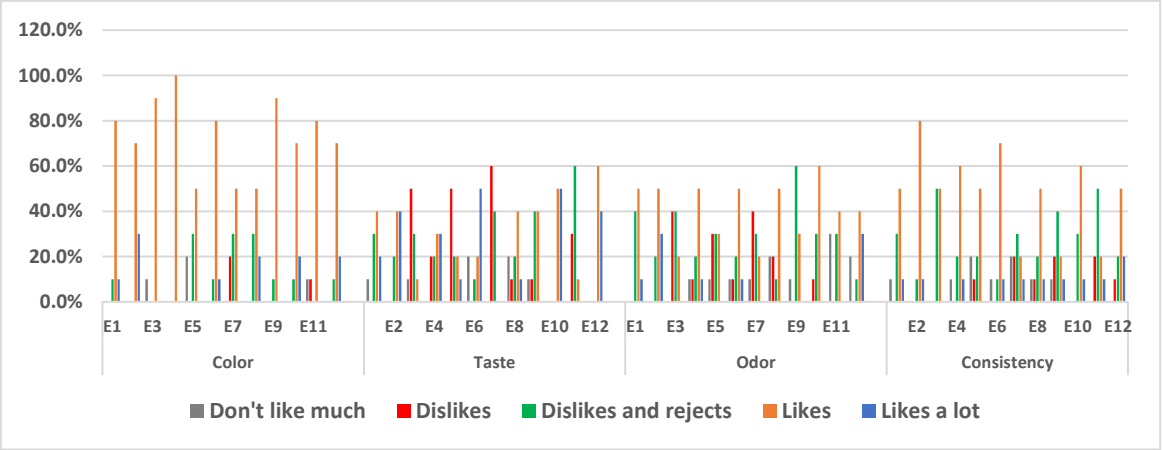
E1: "Dakoua" made from 100% tiger nuts; E2: "Dakoua" made from 85% tiger nuts and 15% millet; E3: "Dakoua" 90% tiger nut and 10% milk.

Fig.8: Acceptability of the different "Dakoua" variants.

Analysis of Figure 2 shows that 90% and 50% of the panelists rated E1 and E3 as "acceptable," respectively, while 60% rated E2 as "not very acceptable." In summary, the results of the sensory analysis show that variants based on 100% and 90% tiger nuts are the most accepted.

3.1.4. Assessment of the organoleptic parameters of tiger nut milks

Figure 9 shows the assessment of the color, taste, smell, and consistency of the different types of milk made from small tiger nuts (PS) and large tiger nuts (GS).



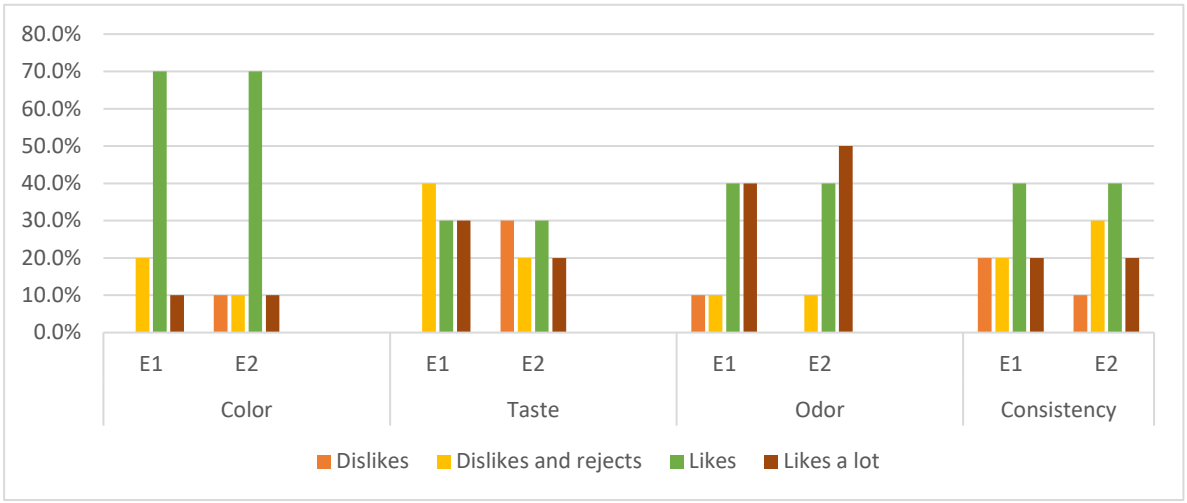
E1: unsoaked small tiger nut milk; E2: unsoaked large tiger nut milk; E3: soaked small tiger nut milk; E4: soaked large tiger nut milk; E5: unsoaked small tiger nut milk, steamed; E6: unsoaked large tiger nut milk, steamed; E7: unsoaked small tiger nut milk, blanched; E8: unsoaked large tiger nut milk, blanched; E9: soaked small tiger nut milk, blanched; E10: soaked large tiger nut milk, blanched. Steamed soaked small tiger nut milk; E8: steamed soaked large tiger nut milk; E9: unsoaked small tiger nut milk, blanched; E10: unsoaked large tiger nut milk, blanched; E11: blanched soaked small tiger nut milk; E12: blanched soaked large tiger nut milk.

Fig.9: Assessment of the color, taste, smell, and consistency of the different small tiger nut (STN) and large tiger nut (LTN) milks.

Figure 9 shows that more than 50% of panelists appreciated the color of all derivative products, with E4 soaked tiger nut milk receiving the most mentions, followed by 100% for all other products. E6, E10, and E12 milks were the most appreciated by the panelists for their taste, with mentions of "really like" and "like," compared to E3, E5, E7, and E11 milks, which were rated "don't like" and "don't like and don't reject." The analysis also shows that E10 milk (60%) has the most pleasant smell, while E9 milk (60%) has the least pleasant smell. Of the milks evaluated, E7, E9, and E11 are the least consistent. According to the analysis results, tiger nut milks are the most appreciated in terms of color (E4), taste (E12), smell (E10), and consistency (E2).

3.1.5. Assessment of the Organoleptic Parameters of Tiger Nut Porridges

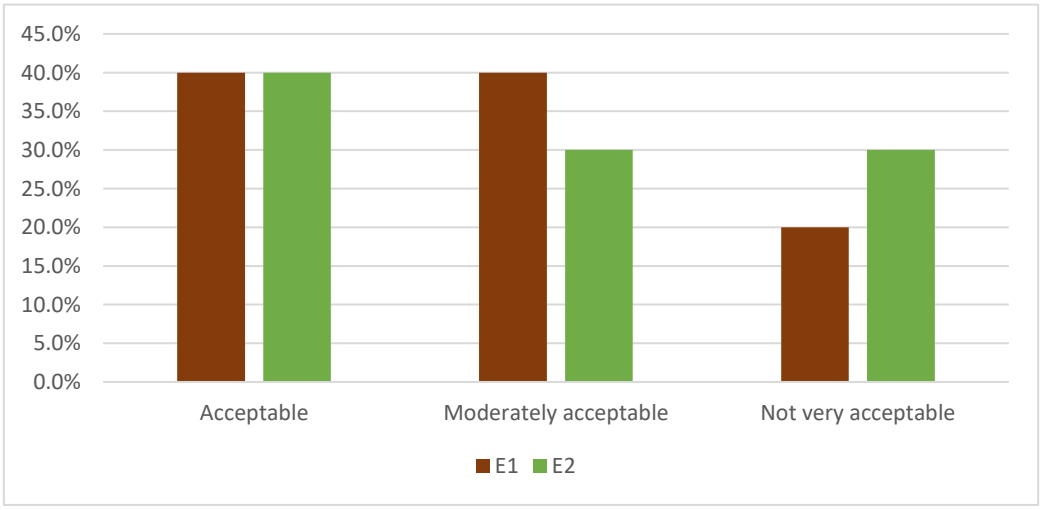
Figures 10 and 11 show the organoleptic test results relating to color, taste, smell, texture, and acceptability of porridges made from the two types of tiger nuts



E1: large tiger nut porridge, and E2: small tiger nut porridge.

Fig.10: Assessment of the color, taste, smell, and consistency of the porridges made from the two tiger nut varieties.

Analysis of Figure 10 shows that the panelists much preferred the color of porridges E1 and E2, with 70% rating them as "like." In terms of smell, 50% of the panelists much preferred E2.



E1: large tiger nut porridge, and E2: small tiger nut porridge.

Fig.11: Acceptability of porridge made from the two varieties of tiger nuts.

Figure 11 shows that 40% of the panelists found E1 to be acceptable or moderately acceptable, while only 20% found it to be unacceptable. These results show that E1 porridge is more acceptable than E2 porridge.

IV. DISCUSSION

Sensory analysis reveals a clear preference for products made from large tiger nuts, especially flours and milks. This can be explained by the organoleptic qualities of large tiger nuts. Their fine texture and milder taste make them more suitable for preparations such as cookies or porridge.

Panelists rated the products made from tiger nuts differently according to the sensory parameters considered in the assessment and acceptability test. Large tiger nuts (GS) were preferred by the panelists for their color, taste, and texture. Seventy percent rated them as "like very much" for color, and 60% did so for taste and texture. Overall, 80% of the panelists found GS to be acceptable. This could be explained by their whitish color and high total sugar content (10.28 ± 0.08%) and reducing sugar content (4.21 ± 0.66%) (Kadjo *et al*, 2023).

The oven-baked cookie (E2) was the most popular due to its taste and color, receiving 90% and 60% ratings,

respectively. It also received the highest overall acceptability rating, at 60%, compared to 30% for E1. This could be explained by the fact that the product is less fatty than the oil-fried cookies. This result is similar to that of Belmadani, N. et al., 2024 who found that sensory testing of freshly stored cookies revealed that most tasters preferred baked tiger nut flour cookies.

The "Dakoua" made with 100% tiger nuts (E1) and 90% tiger nuts and 10% milk (E3) were the most popular, particularly for their taste and smell. Product E2 (85% tiger nut and 15% millet) was the least popular, with 60% of the panelists finding it unacceptable. This could be because these two products meet local consumers' expectations regarding richness and satiety. Tiger nut flour has a considerably higher sucrose concentration (15 g/100 g dry basis) than glucose and fructose, which confirms its natural and desirable sweetness (Belmadani, N. et al., 2024).

Tiger nut milks are the most popular in terms of color (E4), taste (E12), smell (E10), and consistency (E2). This is due to the high sucrose content of tiger nuts, which is appealing to consumers, as well as the higher protein, polyphenol, and mineral content of tiger nut milks (Hernández-Olivas et al., 2022; Zhang et al., 2023)

Panelists prefer large (GS) and small (PS) tiger nut porridges for their color (70%) and smell (50%), respectively. This may be because the white color and smell of tiger nuts are released in the porridge.

V. CONCLUSION

Sensory analyses have shown that products made from large tiger nuts are the most popular and widely accepted. For milks, that it is the color (E4), taste (E12), smell (E10), or consistency (E2). Baked cookies and “dakoua” E1, which is 100% tiger nut, are the most appreciated and accepted by panelists.

REFERENCES

[1] Semdé, Z., Parkouda, C., Tamboura,D., Sawadogo, L. H., 2019. Variability in the physical and nutritional characteristics of tiger nut tubers (Cyperus esculentus L.) grown in Burkina Faso. Science and technology, natural and applied sciences. pp. 21-33

[2] Zhang, S., Li, P., Wei, Z., Cheng, Y., Liu, J., Yang, Y., Wang, Y., Mu, Z. Cyperus (Cyperus esculentus L.): review of its composition, medical efficacy, antibacterial activity, and allelopathic potential. Plants 2022, 11, 1127. https://doi.org/10.3390/plants11091127

[3] Gambo, S., 2005. Importance of tiger nut production in the agricultural development of the Aguié region in Niger. Master's degree in rural economics and sociology. University of Gembloux. 59p.

[4] Aoua., 2008. Business plan of the SA'A federation of Maradi for the marketing of tiger nuts for export 2009-2013. 14p.

[5] Bori, H. Toudou, O. Moumouni, D. M. A., Adam.T. 2018. Tiger nut (Cyperus esculentus) cultivation in Niger: Origin, advantages, and constraints. Journal of Animal & Plant Sciences, Vol. 37, Issue 1: 5997-6007. Accessed on 05/03/2024, 11p.

[6] Bori, Haoua., Oumarou, D. Halima., Dan Guimbo, I., Adam,T. 2023. Nutritional and Mineral Compositions of Tiger Nut (Cyperus esculentus) Tubers from Different Ecotypes in Niger. Asian Journal of Research in Crop Science. Volume 8, Issue 2, Pages 39-48.

[7] Dupont E., 2023. Tiger nuts: an ancient plant rich in history, nutrients, and culinary uses. Available atwww.centreculinaire.com

[8] Ban-koffi, g., Nemlin, s. le Fevre ka. Physicochemical characterization and therapeutic potential of tiger nuts (Cyperus esculentus L. (Cyperaceae). Agron Afr. 2005; 17(1): 63-71

[9] Yali, Y., Xiaoyu, L., Tiehua, Z., Changhui, Z., Shiyao G., Yiling P., Yiling P. 2022. Tiger nut (Cyperus esculentus L.): nutrition, processing, function, and applications. Foods, 11(4), 601; https://doi.org/10.3390/foods11040601.

[10] Adjahossou, V. Naéssé., Dossou, S. J., Charlemagne, G., Samuel, A., Judicaël, L., Ahodonissou, A. G., Alexandre, D. A. 2021. Popular classification and traditional uses of Cyperus Esculentus, a neglected and underutilized species in Benin.

[11] Kadjo, M. M. L. R., Yeboue, K. H., Anin Atchibri, A. L., Farman, O. A., Ahui Bitty, M. L., Kati, C. S. 2023. Evaluation of the physicochemical parameters and nutrients of tiger nut milk powder (Cyperus esculentus L.). EAS Journal of Nutrition and Food Sciences. DOI:10.36349/easjnfs . 2023.v05i05.004. PP. 158-164

[12] Belmadani, N., Kassous, W., Keddar, K., Amtout, L., Hamed, D., Douma-Bouthiba, Z., Costache, V., Gérard, P., Ziar, H. 2024. Functional biscuits based on Cyperus esculentus L. enriched with the probiotic strain Lacticaseibacillus rhamnosus SL42. Foods. 13p. https://doi.org/10.3390/foods13162541

[13] Zhang, RY., Huang, XY., Chen, PX., Li, T., Jiang, MM., Wang, YL., Liu, HM.2023. Un nouveau sucre non centrifuge préparé à partir de farine de souchet (*Cyperus esculentus* L.) : méthodes de préparation et comparaison avec la canne à sucre. Food Res. Int. 174.

[14] Hernández-Olivas, E., Asensio-Grau, A., Calvo-Lerma, J., García-Hernández, J., Heredia, A., Andrés, A. 2022. Teneur et bioaccessibilité des composés bioactifs potentiellement bénéfiques pour la santé maculaire dans les produits à base de souchet. Alimentation. Biosci., 49

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The main zoonoses and their impacts on humans and animals: A literature review

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***Abstract*—** *Zoonoses represent a group of infectious diseases that can be transmitted between animals and humans, posing a significant challenge to public health, veterinary medicine, and other related professions. This article presents a detailed review of the main zoonoses, addressing viral, bacterial, parasitic, and fungal etiological agents , their transmission routes, clinical manifestations, socioeconomic impacts, and prevention strategies. Furthermore, it highlights the effects of zoonoses on both human health and animal welfare. Understanding these diseases is essential for the implementation of integrated health policies, reinforcing the One Health approach, which recognizes the interdependence between the health of humans, animals, and the environment.*

I. INTRODUCTION

Zoonoses represent a diverse group of infectious diseases characterized by their ability to be transmitted from animals to humans and vice versa. It is estimated that more than 60% of emerging infectious diseases in humans originate from animals, with significant implications for public health and the global economy (Halliday et al., 2017).

Increased contact between humans and animals, whether in urban, rural, or wild environments, has raised the incidence of these diseases. Factors such as deforestation, agricultural expansion, globalization, climate change, and population growth contribute to the emergence of new zoonoses (Karesh et al., 2012). Furthermore, the population density of domestic and intensively farmed animals favors the circulation of infectious agents, increasing the risk of transmission to humans.

Zoonoses have a direct impact on humans, manifesting as symptoms ranging from mild to severe and potentially fatal, in addition to generating costs for medical care, loss of productivity, and trade restrictions. In animals, these diseases can lead to morbidity, mortality, decreased productivity, reproductive loss, and suffering, affecting both production animals and pets (WHO, 2020).

This article reviews the main zoonoses, detailing their etiological agents, modes of transmission, clinical manifestations, impacts on humans and animals, and preventive measures. The integration of human medicine, veterinary medicine, and environmental health is essential for mitigating these effects.

Zoonoses represent a significant group of infectious diseases transmitted between animals and humans, with a substantial impact on global public health. It is estimated that more than 60% of human infectious diseases have a zoonotic origin , encompassing viruses, bacteria, parasites, and fungi.

In Brazil, the main zoonoses include leptospirosis, visceral leishmaniasis, hantavirus , toxoplasmosis, rabies, brucellosis, bovine tuberculosis, giardiasis, dermatophytosis , and cutaneous larva migrans .

Leptospirosis, for example, has an annual average of more than 3,600 cases and 375 deaths, with a lethality rate that can reach 40% in some regions. Visceral leishmaniasis, a neglected tropical disease, affects between 200,000 and 400,000 people annually, with approximately 20,000 to 40,000 deaths, making Brazil one of the countries with the highest number of cases.

Hantavirus , transmitted by rodents, accounts for approximately 100 cases annually in Brazil, with a mortality rate of about 46%. Human rabies , although declining due to vaccination programs, still represents a risk, with five deaths recorded in 2025, the highest number since 2018.

Furthermore, diseases such as toxoplasmosis, brucellosis, and bovine tuberculosis continue to pose significant public health challenges, especially in rural areas and communities with limited access to health services. Giardiasis and dermatophytosis , while less lethal, affect a large portion of the population, mainly children and rural workers.

These statistics highlight the importance of epidemiological surveillance, prevention, and control of zoonoses, emphasizing the need for an integrated approach between human, animal, and environmental health. Collaboration among professionals in these areas is essential to reduce the incidence and impact of these diseases on society.

II. LITERATURE REVIEW

Zoonoses Viral

Among viral zoonoses, rabies stands out due to its lethal impact on humans and the importance of its control in domestic animals. Caused by a virus of the genus Lyssavirus , rabies is mainly transmitted through bites from infected mammals, with dogs being the main vector in endemic regions (Fooks et al., 2017).

In humans, the disease manifests with severe neurological symptoms and, without adequate post-exposure treatment, has a mortality rate close to 100%. In animals, rabies causes behavioral changes, aggression, and death, being a critical public health indicator. Another relevant viral zoonosis is Hantavirus, transmitted by rodents, which causes cardiopulmonary syndrome, with high human mortality (Jonsson et al., 2010). In animals, the infection is asymptomatic, but they act as reservoirs, facilitating the spread of the virus.

Avian influenza, caused by type A viruses, has a high zoonotic potential . Infected humans can develop fever, severe respiratory symptoms, and acute respiratory complications, while domestic and wild birds exhibit high mortality, impacting poultry production (Alexander, 2007).

The impact of these viral zoonoses highlights the need for epidemiological surveillance, animal vaccination, biosecurity, and public education to reduce transmission between species.

Zoonoses Bacteria

Bacterial zoonoses exhibit great diversity and clinical relevance. Leptospirosis, caused by Leptospira spp., is transmitted through the urine of infected animals, contaminating water or soil (Levett , 2001). In humans, it manifests with fever, jaundice, hemorrhages, and renal failure, and can lead to death. In animals, it causes fever, jaundice, and abortions, especially affecting cattle, pigs, and rodents.

Salmonellosis is a zoonotic disease of bacterial origin caused by different serotypes of *Salmonella spp. , belonging to the Enterobacteriaceae* family . It is one of the main agents of foodborne infections in the world, with high importance in public health due to its wide distribution and economic impact (GUERRERO et al., 2020).

From an epidemiological point of view, transmission occurs mainly through the ingestion of contaminated animal-derived foods, such as meat, eggs, and milk, in addition to cross-contamination in food handling environments (MELO et al., 2019). Studies indicate that factors such as inadequate hygiene practices, consumption of raw foods, and antimicrobial resistance contribute to maintaining the epidemiological chain of salmonellosis (SANTOS; OLIVEIRA, 2021).

In humans, clinical signs generally manifest acutely, including fever, diarrhea, abdominal pain, nausea, and vomiting. In more severe cases, especially in children, the elderly, and immunocompromised individuals, bacteremia and systemic complications may occur (BRASIL, 2020). In animals, the symptomatology varies according to the species and clinical condition, and can range from diarrhea to septicemia (SILVA et al., 2018).

Treatment is based on fluid and electrolyte replacement, with antibiotic therapy restricted to severe or systemic cases due to the risk of selecting resistant strains (WHO, 2021). The indiscriminate use of antimicrobials in veterinary medicine and animal production is a worrying factor, as it favors the spread of bacterial resistance (ALMEIDA; ROCHA, 2017).

Prevention and control measures include good food hygiene practices, sanitary inspections in production chains, and health education programs aimed at the population. Furthermore, monitoring antimicrobial resistance in *Salmonella spp.* is fundamental for public health and veterinary medicine strategies (FERREIRA et al., 2020).

Therefore, salmonellosis represents a multidimensional challenge, requiring integrated approaches within the One Health concept, which encompasses the interface between human, animal, and environmental health.

Bacterial zoonoses demonstrate the need for food hygiene, sanitary management, and constant monitoring of herds to prevent transmission.

Brucellosis is a bacterial zoonosis with a wide global distribution, caused by species of the genus *Brucella* , affecting domestic animals and humans, and is considered a serious public and animal health problem (CORBEL, 2006). Transmission occurs mainly through direct contact with secretions or tissues of infected animals and through the ingestion of unpasteurized dairy products (SELEEM; BOYLE; SRIRANGANATHAN, 2010). In humans, it manifests as a prolonged febrile illness, associated with fatigue, arthralgia , and systemic complications, with a significant impact on quality of life (PAPPAS et al., 2006).

In the context of livestock production, the disease causes economic losses related to infertility, abortions, and a drop in milk production, being considered one of the main sanitary barriers to the international trade of animals and animal products (GODFROID et al., 2011). For cattle, vaccination with the *B. abortus* S19 strain is an essential strategy in controlling the disease, although it has limitations regarding interference with serological tests (NICOLETTI, 2010).

Globally, eradication programs combine early diagnosis, culling of positive animals, and continuous serological monitoring—measures that have already proven effective in developed countries (OIE, 2018). However, in developing countries, brucellosis remains endemic due to structural and epidemiological surveillance difficulties (DEAN et al., 2012). In this context, the importance of the " One Health" approach, which integrates animal, human, and environmental health for the sustainable control of the disease, is reinforced (FRANCO et al., 2007).

Leptospirosis is a zoonotic disease with a worldwide distribution caused by bacteria of the genus *Leptospira* , characterized as an acute febrile illness of great importance in public health (FAINE et al., 1999). Transmission occurs through contact with water or soil contaminated by the urine of infected animals, mainly rodents, and is favored by floods and poor sanitation conditions (KO; GOARANT; PICARDEAU, 2009). In humans, it can range from mild to severe forms, such as Weil 's syndrome , characterized by liver and kidney failure, as well as hemorrhagic manifestations (BHARTI et al., 2003).

From a veterinary point of view, leptospirosis affects several domestic and production species, causing abortions, infertility, and decreased productivity, resulting in significant economic losses (ELLIS, 2015). Animal infection plays a central role in maintaining the epidemiological cycle, with dogs and rats being important urban reservoirs (LEVETT, 2001).

Early diagnosis of the disease is a challenge, since the clinical signs are nonspecific and easily confused with other febrile illnesses (PICARDEAU, 2017). Control of leptospirosis depends on integrated strategies, such as animal vaccination, rodent population control, improvements in sanitary infrastructure, and health education campaigns (ADLER; DE LA PEÑA MOCTEZUMA, 2010). In the current context, the need for surveillance based on the " One Health" concept is reinforced, uniting animal, human, and environmental health to reduce the impacts of the disease (COSTA et al., 2015).

Zoonoses Parasitic

Parasitic zoonoses include diseases caused by protozoa, helminths, and ectoparasites, with significant impacts on humans and animals.

Toxoplasmosis is a parasitic zoonosis with a worldwide distribution caused by the obligate intracellular protozoan *Toxoplasma gondii* , belonging to the phylum Apicomplexa . It is one of the most prevalent infections among humans and animals, with a significant impact on public health and animal production (MONTOYA; LIESENFELD, 2004). The parasite's life cycle involves definitive hosts, felines, in which sexual reproduction occurs, and various intermediate hosts, including humans, in which asexual forms predominate (DUBEY, 2010).

Transmission to humans occurs primarily through the ingestion of sporulated oocysts present in the environment, via contaminated water and food, or through tissue cysts in undercooked meat. Furthermore, vertical transmission is an important route of infection, potentially causing serious fetal consequences (TENTER; HECKEROTH; WEISS, 2000). In immunocompetent individuals , the disease generally presents with an asymptomatic or mild course, while in immunocompromised individuals it can progress to severe forms, including toxoplasmic encephalitis , pneumonia, and myocarditis (HILL; DUBEY, 2002).

From a veterinary perspective, toxoplasmosis is relevant in livestock, especially sheep and goats, being responsible for significant abortions and neonatal losses (INNES et al., 2009). In felines, as definitive hosts, the parasite is eliminated in feces in the form of oocysts, contaminating the environment and perpetuating the disease cycle (ELMORE et al., 2010). Thus, proper management of domestic cats and control of stray felines become important measures for reducing environmental contamination.

The diagnosis of toxoplasmosis in humans and animals is performed using serological methods, such as ELISA and indirect immunofluorescence , and molecular techniques, such as PCR, which allow for the direct detection of the protozoan's DNA (FERREIRA et al., 2017). In the therapeutic field, treatment is based on combinations of pyrimethamine and sulfadiazine , usually in conjunction with folinic acid , although these drugs are not capable of eliminating tissue cysts, making complete eradication of the infection difficult (MONTOYA; REMINGTON, 2008).

Preventive measures are essential for controlling toxoplasmosis, including food hygiene, consuming properly cooked meat, drinking potable water, and public health education (ROBERT-GANGNEUX; DARDÉ, 2012). In livestock, management strategies, experimental vaccination, and controlling exposure to felines are promising alternatives to reduce the prevalence of the disease (INNES, 2010).

Finally, toxoplasmosis must be understood within the " One Health" paradigm, considering its interaction between animals, humans, and the environment, requiring integrated actions of epidemiological surveillance, health education, and food biosecurity (DUBEY, 2020).

Leishmaniasis is a neglected parasitic disease with a wide geographic distribution, mainly in the North and Northeast regions of Brazil. Caused by protozoa of the genus *Leishmania* , the disease manifests in cutaneous, mucosal, and visceral forms, the latter being the most serious and potentially fatal if not properly treated (GONTIJO; MELO, 2004).

Visceral leishmaniasis is transmitted primarily by sandflies of the genus *Lutzomyia* , especially *Lutzomyia. longipalpis* , the main vector in Brazil (SILVA et al., 2023). Human infection occurs through the bite of the infected insect, introducing promastigotes that transform into amastigotes in the host cells, triggering varied clinical manifestations (GAZZINELLI et al., 2025).

Epidemiological studies indicate changes in the distribution patterns of visceral leishmaniasis in Brazilian territory. Silva et al. (2023) observed, between 2007 and 2020, a high incidence in municipalities in the North and Northeast regions, with expansion in urban areas due to disordered urbanization and precarious socioeconomic conditions.

Diagnosis of the disease involves laboratory methods, such as the search for amastigotes in bone marrow, liver, or spleen smears, in addition to serological and molecular tests (GONTIJO; MELO, 2004). Conventional treatment is based on medications such as liposomal amphotericin B , which is effective but has significant adverse effects. Recent research has sought safer and more effective therapeutic alternatives (SILVA et al., 2023).

Leish-Tec® , targeting canine visceral leishmaniasis , stand out . Studies indicate that the vaccine induces an effective immune response in dogs, reducing the transmission of the parasite to the vector (GAZZINELLI et al., 2025). Integrated strategies of surveillance, vector control, and health education are essential to combat the disease and minimize its spread (GONTIJO; MELO, 2004).

In summary, visceral leishmaniasis represents a public health challenge in Brazil. Advances in scientific research are essential to improve diagnoses, treatments, and preventive measures, aiming to reduce morbidity and mortality and mitigate its socioeconomic impact (SILVA et al., 2023; GAZZINELLI et al., 2025; GONTIJO; MELO, 2004).

Giardiasis is an intestinal parasitic infection caused by the flagellated protozoan *Giardia. G. duodenalis* (also known as *G. lamblia* or *G. intestinalis*), which affects humans and animals, is a zoonosis with a wide global distribution (FREITAS et al., 2018). Its importance in public health is related to its high prevalence, especially in regions with inadequate sanitation conditions, and its potential to cause outbreaks of waterborne and foodborne diarrhea (FENG; XIAO, 2019).

Epidemiologically , transmission occurs via the fecal-oral route, mainly through the ingestion of cysts present in contaminated water and food or through direct contact between infected individuals and animals (OLIVEIRA et al., 2021). Preschool children, immunocompromised individuals , and populations in situations of socioeconomic vulnerability represent the most susceptible groups (BRASIL, 2019).

The clinical signs of giardiasis range from asymptomatic cases to acute or chronic manifestations. Among the most common symptoms are intermittent or persistent diarrhea, abdominal pain, nausea, flatulence, and weight loss. In prolonged cases, there may be malabsorption of nutrients and impaired child development (CAMPOS et al., 2020).

Treatment for giardiasis is based on the use of antiparasitic drugs, with metronidazole , tinidazole, and albendazole being the most commonly used and effective drugs (ESPOSITO; LUCAS, 2017). However, emerging drug resistance in some *Giardia strains* represents a growing challenge for therapy (FENG; XIAO, 2019). Furthermore, supportive measures, such as hydration and electrolyte replacement, may be necessary in cases of severe diarrhea.

Prevention is closely related to personal hygiene practices, access to drinking water, and basic sanitation measures. Epidemiological surveillance and health education programs are fundamental to reducing the incidence of giardiasis, especially in vulnerable communities (SILVA; BARBOSA, 2018).

Therefore, giardiasis is a parasitic disease of global relevance, requiring integrated actions within the framework of One Health, considering the interface between human, animal, and environmental health.

Zoonoses Fungal

Fungal zoonoses include diseases such as dermatophytosis , caused by fungi of the genus Trichophyton , transmitted through direct contact with infected animals or contaminated surfaces (Weitzman & Summerbell , 1995). In humans, it causes circular skin lesions, itching, and discomfort. In animals, it causes alopecia, scaling, and intense itching, impacting the well-being of pets and farm animals.

zoonotic mycoses include infections caused by Sporothrix spp., usually transmitted by cats, causing skin lesions in humans and respiratory and cutaneous symptoms in felines (Barros et al., 2011).

Pharmacological treatment

Pharmacological treatment of zoonoses varies according to the etiological agent and the severity of the infection. In viral zoonoses , such as rabies, immediate post-exposure intervention involves the administration of the human rabies vaccine combined with specific immunoglobulin , a measure that is almost entirely effective in preventing the disease when performed correctly (WHO, 2020). In Hantavirus infections , although there are no specific antivirals, clinical management is essentially supportive, including hydration, oxygen therapy , and intensive care for acute cardiopulmonary syndrome (CDC, 2020). For avian influenza , antivirals such as oseltamivir or zanamivir can reduce viral replication and severe respiratory complications, especially in confirmed human cases.

In bacterial zoonoses , the use of antibiotics is the basis of treatment. In leptospirosis , penicillin and doxycycline are used, with greater success when started early. Human brucellosis requires a combination of doxycycline and rifampicin , while severe salmonellosis may require cephalosporins or fluoroquinolones , always considering local bacterial resistance (WHO, 2020).

Parasitic zoonoses include infections caused by protozoa and helminths. In toxoplasmosis , the combination of pyrimethamine , sulfadiazine , and folinic acid is indicated, while human visceral leishmaniasis is treated with pentavalent antimonials or amphotericin. Liposomal , and infected dogs receive allopurinol or miltefosine , when permitted (Alvar et al., 2012). Giardiasis uses metronidazole or fenbendazole , depending on the species and severity.

For fungal zoonoses , such as dermatophytosis , treatment combines topical antifungals (clotrimazole , miconazole) with systemic antifungals (itraconazole , terbinafine) in extensive or resistant cases (Weitzman & Summerbell , 1995). The success of treatment depends on early identification of the agent, therapeutic adherence, clinical monitoring, and integration with preventive measures such as environmental control, personal hygiene, and animal vaccination, ensuring clinical efficacy and reducing the risk of reinfection.

PREVENTION MEASURES

Government agencies play a central role in the prevention and control of zoonoses, implementing strategies that involve public health, epidemiological surveillance, and education. Mandatory vaccination programs for dogs and cats against rabies, coordinated by health departments and veterinary agencies, have significantly reduced the incidence of the disease in several regions (WHO, 2020). Herd control and vaccination of cattle against brucellosis, leptospirosis, and other bacterial zoonoses is promoted by agencies such as the Ministry of Agriculture, aiming to protect both animals and humans.

Epidemiological surveillance is carried out by agencies such as the CDC in the United States and the Ministry of Health in Brazil, monitoring outbreaks of emerging zoonoses, such as Hantavirus, avian influenza, and leishmaniasis, allowing for rapid responses. Sanitary inspection of food of animal origin, carried out by regulatory bodies, ensures food safety, preventing the transmission of salmonellosis , toxoplasmosis, and other foodborne zoonoses.

MAIN ZOONOSES AND THE ROLE OF THE VETERINARIAN IN PUBLIC HEALTH

Zoonoses represent a group of infectious diseases transmitted between animals and humans, notably rabies, leptospirosis, brucellosis, bovine tuberculosis, toxoplasmosis, visceral leishmaniasis, giardiasis, and dermatophytosis . Increasing urbanization, environmental changes, and the intensification of animal production have amplified the risk of transmission of these diseases, making them a significant concern for global public health.

Veterinarians play a crucial role in the prevention and control of zoonoses, working in epidemiological surveillance, diagnosis, clinical management, and health education. Studies indicate that veterinarians have a superior understanding of zoonotic pathogens and greater proficiency in diagnosing these diseases compared to human physicians (Garcia-Sanchez et al., 2023). Furthermore, their role in the early detection and monitoring of diseases in animal populations allows for rapid responses

to outbreaks, mitigating risks to human health (Melo et al., 2020).

The " One Health" approach , which integrates the human, animal, and environmental dimensions of health, reinforces the importance of collaboration among professionals in these areas for the implementation of effective strategies for the prevention and control of zoonoses (CDC, 2025). In this context, the veterinarian is essential not only in the direct care of animals, but also as a public health agent, contributing significantly to the promotion of collective health and food safety.

Veterinary sanitary control is a fundamental component of public health, as it acts directly in the prevention of zoonoses, which are diseases transmissible between animals and humans. Its relevance is part of the One Health concept, which recognizes the interdependence between animal, human, and environmental health (FERREIRA et al., 2020). In this context, different areas of action complement each other to reduce epidemiological risks and guarantee food and sanitary safety.

Sanitary inspection and surveillance play a central role in this process. The inspection of food of animal origin ensures that meat, eggs, milk, and dairy products are free from biological, chemical, and physical contaminants, preventing outbreaks of diseases such as salmonellosis , listeriosis , and brucellosis (SILVA et al., 2020). The inspection of slaughterhouses ensures that the slaughter, processing, and distribution stages meet hygiene and sanitation standards, preventing the spread of pathogens and protecting the end consumer (GUERRERO et al., 2020).

In the context of companion animal control, several measures are implemented. Quality control involves the adoption of appropriate and regulated veterinary practices to ensure the health of these animals and reduce the risk of transmission of zoonoses such as leishmaniasis and toxoplasmosis (OLIVEIRA; SOUSA, 2021). Anti-rabies vaccination represents one of the most effective and traditional strategies, since rabies is a lethal zoonosis that still poses a threat in developing countries (BRASIL, 2019). Castration, in addition to contributing to population control, reduces the circulation of stray animals, which can be vectors of various diseases. Responsible ownership is fundamental to ensuring continuous care with feeding, hygiene, vaccination and veterinary consultations, reducing abandonment and, consequently, the epidemiological risk (SANTOS; OLIVEIRA, 2021).

Epidemiological surveillance is another essential axis. The notification of zoonoses allows for the systematic monitoring of diseases of public health relevance, such as leptospirosis, leishmaniasis, and rabies, enabling rapid responses from health authorities (FERREIRA et al., 2020). Monitoring outbreaks ensures the early identification of new threats and prevents their spread, while containment measures, such as isolation, disinfection, and restriction of animal movement, are applied to reduce propagation in emergency situations (MELO et al., 2019).

Prophylaxis and sanitary management in herds also play a strategic role. Vaccination in herds protects not only the animals, but also rural workers and consumers, preventing diseases such as brucellosis and bovine tuberculosis (GUERRERO et al., 2020). The control of parasites, such as ticks and helminths, reduces the incidence of diseases that can compromise both animal productivity and human health, such as babesiosis and ancylostomiasis (OLIVEIRA et al., 2021).

Another key pillar is health education, which promotes behavioral changes and raises public awareness. Biosecurity encompasses practical preventive measures in breeding and handling environments, such as facility disinfection and the use of personal protective equipment, reducing the risk of pathogen dissemination (SILVA; BARBOSA, 2018). Educational campaigns are tools for social mobilization, sensitizing communities about animal care and disease prevention. Food hygiene is equally relevant, as the proper preparation of animal-derived foods prevents gastrointestinal illnesses and food poisoning (CAMPOS et al., 2020). Finally, awareness of the risks of contact with wild animals highlights potential emerging zoonoses, such as spotted fever and arboviruses , which often originate from this host group (FENG; XIAO, 2019).

In this way, every detail of veterinary sanitary control, from food inspection to health education, contributes to an integrated network for the prevention of zoonoses. The adoption of coordinated measures between public bodies, health professionals and society is essential to minimize the impacts of zoonotic diseases , guarantee food safety and protect both animal and human health.

VETERINARY HEALTH CONTROL AND ZOONOSIS PREVENTION

Sanitary Inspection and Surveillance

- Food inspection
- Slaughterhouse supervision

Companion Animal Control

- Quality control
- Rabies vaccination
- Neutering
- Responsible ownership

Epidemiological Surveillance

- Zoonosis notification

- Outbreak monitoring
- Containment measures

Prophylaxis and Sanitary Management

- Herd vaccination
- Parasite control

Health Education

- Biosafety
- Educational campaigns
- Food hygiene
- Risks from wild animals

III. DISCUSSION

Zoonoses have direct and indirect effects on humans and animals, impacting health, well-being, productivity, and the economy. In humans, they can lead to hospitalization, mortality, and chronic complications, as well as generating medical and social costs. In animals, they cause suffering, decreased food production, abortions, infertility, and death, affecting food security and the agricultural economy (WHO, 2020).

Prevention requires an integrated *One Health approach* , involving veterinarians, physicians, environmentalists, and public policy (ZINSSTAG et al., 2011). Strategies include: animal vaccination, such as dogs against rabies and cattle against brucellosis; vector control, such as sandflies , rodents, and mosquitoes; environmental and personal hygiene, with emphasis on basic sanitation, access to potable water, and proper waste management; public education and awareness about risks and prevention methods; and epidemiological surveillance, which includes the continuous monitoring of animal and human populations.

The socioeconomic impact of zoonoses is significant, including losses in animal production, increased healthcare costs, and international trade restrictions. Integration between human, animal, and environmental health is essential to mitigate these effects and ensure sustainability.

Furthermore, antimicrobial resistance in zoonotic pathogens is emerging as one of the greatest global challenges. Species such as *Salmonella spp.* and *Escherichia coli* have shown a high capacity to develop resistance, threatening the effectiveness of antibiotics used in both humans and animals (FERREIRA et al., 2020). This phenomenon demonstrates how inadequate sanitary management practices, indiscriminate use of antimicrobials in herds, and surveillance failures can have transnational repercussions.

In the context of emerging diseases, it is observed that more than 60% of infectious agents affecting humans have a zoonotic origin, which reinforces the need for integrated surveillance programs (JONES et al., 2008). Recent epidemics, such as avian influenza and coronavirus outbreaks , have demonstrated the potential of zoonoses to generate health, social, and economic crises on a global scale (ALEXANDER, 2007).

The adoption of biosecurity measures on rural properties is equally indispensable, reducing the entry and spread of infectious agents. Proper waste management, quarantine of newly acquired animals, and maintenance of good hygiene practices in production are fundamental to ensuring public health (OIE, 2018).

Another crucial point is health education, which proves to be one of the most effective instruments for prevention. Campaigns that address responsible pet ownership, rabies vaccination, and simple food hygiene measures are capable of significantly reducing the incidence of diseases (SANTOS; OLIVEIRA, 2021).

From an economic standpoint, zoonoses are estimated to cause billions of dollars in annual losses, both due to animal mortality and decreased productivity, as well as hospital costs and reduced international trade in animal products (WORLD BANK, 2012). Therefore, prevention and control should not be considered merely investments in health, but also strategies for sustainable development.

In summary, the integrated approach proposed by the *One Health concept* represents not only a health necessity, but also a strategic requirement in the face of globalization, climate change, and increased interactions between humans, animals, and the environment. International cooperation, coupled with effective public policies, constitutes the most promising path to reducing the impacts of zoonoses on public health and the global economy.

IV. CONCLUSION

Zoonoses pose a global challenge, affecting both humans and animals. Understanding etiological agents, transmission routes, clinical manifestations, and socioeconomic impacts is fundamental for the development of effective prevention policies. An interdisciplinary approach, based on the One Health concept, is essential to reduce the incidence of these diseases, protect public health, and promote animal welfare.

REFERENCES

[1] ADLER, B.; DE LA PEÑA MOCTEZUMA, A. Leptospira and Leptospirosis . *Veterinary. Microbiology* , vol. 140, no. 3-4, p. 287-296, 2010.

[2] ALEXANDER, DJ An overview of the epidemiology of avian influenza. *Vaccine* , vol. 25, no. 30, p. 5637–5644, 2007.
[3] ALMEIDA, AC; ROCHA, AC Antimicrobial resistance in *Salmonella spp.* of animal origin. *Revista de Ciências Veterinárias* , v. 25, n. 2, p. 45-52, 2017.
[4] ALVAR, J. et al. Leishmaniasis worldwide and global estimates of its incidence. *PLoS One*, v. 7, n. 5, e35671, 2012.
[5] BARROS, M. B.; DE ALMEIDA PAES, R.; SCHUBACH, A. O. Sporotrichosis: an update on epidemiology, etiopathogenesis, laboratory and clinical therapeutics. *An Bras Dermatol*, v. 86, n. 5, p. 1003–1013, 2011.
[6] BHARTI, AR et al. Leptospirosis : a zoonotic disease of global importance . *The Lancet Infectious Diseases* , vol. 3, no. 12, p. 757-771, 2003.
[7] BRAZIL. Ministry of Health. *Manual for Surveillance and Control of Water and Foodborne Diseases* . Brasília: Ministry of Health, 2019.
[8] BRAZIL. Ministry of Health. *Integrated Manual for Surveillance, Prevention and Control of Foodborne Diseases* . Brasília: Ministry of Health, 2020.
[9] BRAZIL. Ministry of Health. *Human Brucellosis* . 2024. Available at: https://www.gov.br/saude/pt-br/assuntos/saude-de-aaz/b/brucelose-humana .
[10] BRAZIL. Ministry of Health. *Dermatophytoses* . 2024. Available at: https://www.gov.br/saude/pt-br/assuntos/saude-de-aaz/d/dermatofitoses .
[11] BRAZIL. Ministry of Health. *Giardiasis* . 2024. Available at: https://www.gov.br/saude/pt-br/assuntos/saude-de-aaz/g/giardiase .
[12] BRAZIL. Ministry of Health. *Human rabies* . 2025. Available at: https://www.gov.br/saude/pt-br/assuntos/saude-de-aaz/r/raiva/raiva-humana .
[13] BRAZIL. Ministry of Health. *Epidemiological situation of leptospirosis in Brazil* . 2025. Available at: https://www.gov.br/saude/pt-br/assuntos/saude-de-aaz/l/leptospirose/situacao-epidemiologica .
[14] BRAZIL. Ministry of Health. *Health launches panels to monitor leishmaniasis in Brazil* . 2024. Available at: https://www.gov.br/saude/pt-br/assuntos/noticias/2024/setembro/saude-lanca-paineis-para-monitorar-leishmanioses-no-brasil .
[15] BRAZIL. Ministry of Health. *Toxoplasmosis* . 2024. Available at: https://www.gov.br/saude/pt-br/assuntos/saude-de-aaz/t/toxoplasmose .
[16] BRAZIL. Ministry of Health. *Bovine Tuberculosis* . 2024. Available at: https://www.gov.br/saude/pt-br/assuntos/saude-de-aaz/t/tuberculose-bovina .
[17] CAMPOS, JP et al. Clinical manifestations of giardiasis in vulnerable populations: a narrative review. *Pan American Journal of Public Health* , v. 44, n. 3, p. 1-10, 2020.
[18] CORBEL, MJ *Brucellosis in humans and animals* . Geneva : World Health Organization , 2006.
[19] COSTA, F. et al. Global morbidity and mortality of leptospirosis: a systematic review. *PLoS Neglected Tropical Diseases*, v. 9, n. 9, e0003898, 2015.
[20] DEAN, A. S. et al. Clinical manifestations of human brucellosis: a systematic review and meta-analysis. *PLoS Neglected Tropical Diseases*, v. 6, n. 12, e1929, 2012.
[21] DRAUZIO VARELLA. Hantavirus : hantavirus case fatality rate in Brazil is almost 40%. 2025. Available at: https://drauziovarella.uol.com.br/coluna-da-mariana-varella/hantavirose-taxa-de-letalidade-por-hantavirus-no-brasil-e-de-quase-40/ .
[22] DUBEY, JP *Toxoplasmosis of animals and humans* . 2nd ed. Boca Raton : CRC Press, 2010.
[23] DUBEY, J. P. Advances in toxoplasmosis research in 2020. *Parasitology International*, v. 76, p. 102–110, 2020.
[24] ELIS, W. A. Animal leptospirosis. *Current Topics in Microbiology and Immunology*, v. 387, p. 99-137, 2015.
[25] ELMORE, S. A. et al. *Toxoplasma gondii*: epidemiology, feline clinical aspects, and prevention. *Trends in Parasitology*, v. 26, n. 4, p. 190-196, 2010.
[26] ESPOSITO, D. H.; LUCAS, C. M. Current treatment options for giardiasis. *Clinical Infectious Diseases*, v. 64, n. 10, p. 1302-1307, 2017.
[27] FAINE, S. et al. *Leptospira and leptospirosis*. 2. ed. Melbourne: MediSci, 1999.
[28] FENG, Y.; XIAO, L. Zoonotic potential and molecular epidemiology of *Giardia* species and giardiasis. *Clinical Microbiology Reviews*, v. 32, n. 2, p. 1-22, 2019.
[29] FERREIRA, FP et al. The use of PCR in toxoplasmosis diagnosis : advances and challenges . *Brazilian Journal of Veterinary Parasitology* , v. 26, n. 2, p. 151-160, 2017.
[30] FERREIRA, RP et al. Monitoring antimicrobial resistance in *Salmonella spp.:* implications for public health. *Brazilian Journal of Epidemiology* , v. 23, n. 4, p. 1-12, 2020.
[31] FHOOKS, AR et al. Current status of rabies and prospects for elimination . *The Lancet* , vol. 390, n. 10105, 2017.
[32] FREITAS, JL et al. Prevalence of giardiasis in different regions of Brazil: a systematic review. *Revista de Saúde e Pesquisa* , v. 11, n. 2, p. 45-55, 2018.
[33] GAZZINELLI, RT et al. Development and efficacy of the Leish-Tec® vaccine . *Journal of Applied Immunology* , 2025.
[34] GODFROID, J. et al. In terrestrial brucellosis Wildlife *Review Scientifique et Technique (OIE)* , v. 30, no. 1, p. 27-42, 2011.
[35] GONTIJO, CMF; MELO, MN. Epidemiology and control of visceral leishmaniasis in Brazil. *Brazilian Journal of Epidemiology* , v. 7, n. 3, p. 338-350, 2004.
[36] GUERRERO, JL et al. Epidemiology of salmonellosis in Brazil: a literature review. *Pan American Journal of Public Health* , v. 44, n. 2, p. 23-30, 2020.
[37] HILL, D.; DUBEY, J. P. *Toxoplasma gondii*: transmission, diagnosis and prevention. *Clinical Microbiology and Infection*, v. 8, n. 10, p. 634-640, 2002.
[38] INNES, E. A. A brief history and overview of *Toxoplasma gondii*. *Zoonoses and Public Health*, v. 57, p. 1-7, 2010.
[39] INNES, E. A. et al. *Toxoplasma gondii*: the role of parasite-host interaction in pathogenesis of ovine abortion. *Veterinary Parasitology*, v. 159, p. 262-266, 2009.
[40] KO, A. I.; GOARANT, C.; PICARDEAU, M. *Leptospira*: the dawn of the molecular genetics era for an emerging zoonotic pathogen. *Nature Reviews Microbiology*, v. 7, n. 10, p. 736-747, 2009.
[41] LEVETT, P. N. Leptospirosis. *Clinical Microbiology Reviews*, v. 14, n. 2, p. 296-326, 2001.

[42] MELO, TS et al. Epidemiological chain of salmonellosis : implications for public health. *Revista de Saúde Pública* , v. 53, n. 1, p. 100-108, 2019.
[43] MONTOYA, JG; LIESENFELD, O. Toxoplasmosis . *The Lancet* , vol. 363, no. 9425, p. 1965-1976, 2004.
[44] MONTOYA, JG; REMINGTON, JS Management of *Toxoplasma gondii* infection during Pregnancy . *Clinical. Infectious Diseases* , vol. 47, no. 4, p. 554-566, 2008.
[45] NICOLETTI, P. Brucellosis : past , present and future. *Prilozi* , vol. 31, no. 1, p. 21-32, 2010.
[46] OIE – World Organisation for Animal Health. *Terrestrial Animal Health Code* . Paris: OIE, 2018.
[47] OLIVEIRA, AR et al. Risk factors associated with giardiasis in human and animal populations. *Brazilian Journal of Veterinary Parasitology* , v. 30, n. 4, p. 1-9, 2021.
[48] PAPPAS, G. et al. The new global map of human brucellosis. *The Lancet Infectious Diseases*, v. 6, n. 2, p. 91-99, 2006.
[49] PICARDEAU, M. Diagnosis and epidemiology of leptospirosis. *Med Mal Infect*, v. 43, n. 1, p. 1-9, 2017.
[50] ROBERT-GANGNEUX, F.; DARDÉ, ML Epidemiology of and diagnostic strategies for toxoplasmosis . *Clinical Microbiology Reviews* , vol. 25, no. 2, p. 264-296, 2012.
[51] SANTOS, LR; OLIVEIRA, SD *Salmonella spp.* in food: risks and prevention. *Food Hygiene* , v. 35, n. 289, p. 20-27, 2021.
[52] SELEEM, MN; BOYLE, SM; SRIRANGANATHAN, N. Brucellosis : a re-emerging Zoonosis . *Veterinary. Microbiology* , vol. 140, no. 3-4, p. 392-398, 2010.
[53] SILVA, AP et al. Spatial distribution of visceral leishmaniasis in Brazil: analysis 2007-2020. *Revista de Saúde Pública* , 2023.
[54] SILVA, ME; BARBOSA, AC. Strategies for giardiasis prevention: a public health focus. *Journal of Epidemiology and Infection Control* , v. 8, n. 1, p. 89-95, 2018.
[55] TENTER, A. M.; HECKEROTH, A. R.; WEISS, L. M. *Toxoplasma gondii*: from animals to humans. *International Journal for Parasitology*, v. 30, p. 1217-1258, 2000.

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The level of self-esteem of young girls aged 12 to 14 years old from a municipality in the Mucuri Valley who practice volleyball

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***Keywords*— Self-esteem, Adolescence, Volleyball, Sports practice, Mental health, Social development.**

***Abstract*—** *This study investigated the self-esteem levels of female adolescents, aged 12 to 14, who practiced volleyball in a sports project in the Mucuri Valley. The Rosenberg Self-Esteem Scale (1965), adapted by Silva and Nunes (2011), was used and applied to 14 participants. The applied research, with a quantitative approach, showed that all athletes presented self-esteem levels ranging from average to high, with no cases of low self-esteem. Positive responses indicated recognition of qualities and personal satisfaction, while negative responses indicated specific insecurities. The practice of volleyball was associated with increased self-confidence, socialization, and a sense of belonging. The results corroborate studies that link team sports to improved emotional health and self-image in young people. It is concluded that volleyball contributes significantly to the psychological and social development of adolescent girls, reinforcing the importance of sports policies focused on youth well-being.*

I. INTRODUCTION

Volleyball is a team sport created in 1895 in the United States by William George Morgan, with the aim of developing a less aggressive physical activity than basketball, suitable for practitioners of different ages (SANTOS, 2015). Initially called *mintonette* , the sport underwent adaptations until it acquired its basic rules, consolidating itself as a recreational and competitive practice at the beginning of the 20th century (OLIVEIRA, 2017). Its international expansion was favored by the work of the YMCA (Young Men's Christian Association), being introduced in several countries, including Brazil, in the first decades of the last century (SILVA; MENDES, 2018). The institutionalization of volleyball occurred with the creation of the Fédération Internationale de Volleyball (FIVB) in 1947, which contributed to its inclusion in the Olympic Games in 1964. In Brazil, the sport became popular in schools and clubs, playing a relevant role in the sporting and social development of young people (COSTA, 2016). Thus, volleyball has established itself as a prominent global sport with broad historical, social, and sporting relevance.

Several countries stand out on the international volleyball scene, in both men's and women's categories. Nations such as Brazil, Russia, Italy, and the United States accumulate titles in competitions such as the Olympic Games, the Nations League, and the World Championship (FIVB, 2021). Brazil, for example, is a global benchmark with multiple Olympic and world titles (Brazilian Volleyball Confederation, 2020). Serbia has excelled especially in women's volleyball (Lopes; Moura, 2022). Japan was a pioneer in the sport in Asia, maintaining tradition and strong performance (Yamamoto, 2019).

Volleyball, in addition to being a competitive sport, also plays a relevant role in promoting health and

social integration. Its practice contributes to the development of motor coordination, agility, and physical endurance (FERREIRA; LIMA, 2020). As a team sport, it also favors teamwork, socialization, and respect for rules (SOUZA; ALMEIDA, 2019). In school and community environments, volleyball is widely used as a recreational tool, providing moments of leisure and well-being (CARVALHO, 2018). Regular activity is associated with the prevention of cardiovascular diseases and the control of body weight, being indicated in public health programs (OLIVEIRA; SANTOS, 2021). Furthermore, it can be adapted for different age groups and physical conditions, which expands its access and benefits (MARTINS, 2022). Studies indicate that sports like volleyball reduce stress and anxiety levels, promoting mental health (PEREIRA et al., 2020). Thus, volleyball is established as a sporting practice with high pedagogical, therapeutic, and social value.

Sports practice during adolescence, such as volleyball, is fundamental for the physical, emotional, and social development of young people. It contributes to the formation of healthy habits, improves self-esteem, and promotes teamwork (SOUZA; ALMEIDA, 2019). Furthermore, it helps prevent risky behaviors and combat sedentary lifestyles (FERREIRA; LIMA, 2020). Sport also has a positive impact on discipline and academic performance (PEREIRA et al., 2020). Therefore, volleyball becomes an educational tool and promoter of comprehensive health during adolescence.

Adolescence is a phase of human development characterized by profound physical, cognitive, emotional, and social transformations that directly influence the formation of identity and how the individual relates to themselves and their surrounding environment (Silva & Nunes, 2011). One of the central aspects of this process is the construction of self-esteem, defined as the subjective evaluation that the individual makes about their own worth, ability, and social acceptance (Harter, 1999).

During this stage, self-esteem can be influenced both positively and negatively, depending on experiences in different contexts, such as family, school, and the sports environment. Sports practice, in particular, has been recognized as an important tool for the psychological and social development of adolescents, promoting benefits that go beyond physical health, such as improved self-confidence, discipline, teamwork, and socialization (Weinberg & Gould, 2017).

Volleyball, a team sport that demands constant communication and cooperation among participants, offers a conducive environment for strengthening self-esteem, especially for girls in the process of identity formation (Ferreira & Motta, 2010). Through sport, adolescent girls have the opportunity to experience challenges, achieve goals, receive recognition, and learn to cope with successes and failures, factors that directly impact the construction of a positive self-image and personal value.

In the context of this municipality, there is a growing interest in promoting sports projects aimed at introducing women to volleyball, which seek not only technical development but also the emotional and social well-being of the participants. Therefore, it becomes relevant to investigate the self-esteem levels of these young women, seeking to understand how the practice of volleyball can positively influence their self-perception and mental health.

This study aims to evaluate the self-esteem level of female adolescents, aged between 12 and 14 years, who practice volleyball in a sports project in a city in the Mucuri Valley, using the Rosenberg Self-Esteem Scale (1965), adapted for Brazil by Silva and Nunes (2011).

JUSTIFICATION

The choice of this theme is based on the importance of self-esteem for the healthy development of adolescents, especially regarding its impact on school performance, mental health, and social relationships (Harter, 1999). Low self-esteem during adolescence can lead to anxiety, social isolation, and difficulties in facing daily challenges, compromising the potential for personal and academic growth (Silva & Nunes, 2011).

On the other hand, the regular practice of sports activities has proven to be a facilitating agent in promoting self-esteem, especially among young women, who frequently face greater barriers to participation and recognition in sports (Ferreira & Motta, 2010). Volleyball, in particular, stands out for its collaborative characteristics and encouragement of teamwork, factors that contribute to the development of self-confidence and a sense of belonging.

In this municipality, sports programs aimed at adolescents are an important strategy for social inclusion and health promotion. However, there is a gap in the local literature regarding the evaluation of the psychological benefits of this sporting activity, especially concerning self-esteem.

Therefore, this study seeks to fill this gap, offering data and analyses that can support teachers, coaches, and sports managers in developing actions that promote not only the technical development of athletes, but also their emotional well-being. Thus, it is hoped to contribute to the holistic development of these adolescents, preparing them for the challenges of life inside and outside of sports.

II. METHODOLOGY

This study is characterized as an original, applied research paper, as its objective is to generate knowledge that can be used in practice, contributing to a better understanding of self-esteem in adolescent volleyball players. A quantitative approach is adopted, combining numerical analysis of the collected data with qualitative interpretation for a better understanding of the results within the social and sporting context of the participants.

The research used the data collection method, which consists of the systematic collection of information directly from the research subjects, through the application of specific instruments, allowing a detailed view of the reality studied.

The study population comprised 23 female adolescents, aged between 12 and 14 years, who regularly participated in a volleyball initiation project in a city in the Mucuri Valley. The sample consisted of 14 students, corresponding to 60.87% of the population, selected based on their attendance at activities and availability to participate in the research, respecting the criterion of informed consent from their guardians.

For data collection, the Rosenberg Self-Esteem Scale (1965) was used, a widely recognized and validated instrument for assessing global self-esteem. The version applied corresponds to the Brazilian adaptation made by Silva and Nunes (2011), which preserves the validity and reliability of the instrument in our cultural context. The scale consists of 10 items, which assess both positive and negative aspects of self-esteem, and is answered using a four-point Likert scale.

The questionnaire was administered individually, in a private and quiet environment, aiming to guarantee the privacy and comfort of the participants, as well as ensuring the reliability of the responses. The research followed ethical principles, with the signing of the Informed Consent Form by the legal guardians of the adolescents, in accordance with current regulations.

The data obtained were organized and tabulated for quantitative analysis. The descriptive analysis will be presented through graphs and tables that show the distribution of self-esteem scores among the participants. In addition, an interpretive qualitative analysis will be conducted, relating the numerical results to the social, sporting, and psychological context of the students, with the aim of providing a broader and deeper understanding of the phenomenon studied.

III. RESULTS

Applying the Rosenberg Self-Esteem Scale to the 14 athletes allowed for the analysis of responses by question and the total score of each participant. The resulting graphs show that:

In the positive questions (1, 2, 3, 6 and 7), the responses were concentrated at levels 3 (agree) and 4 (strongly agree), indicating that the athletes recognize their qualities and, in general, are satisfied with themselves.

In the negative questions (4, 5, 8, 9 and 10), there was a predominance of intermediate responses (2 and 3), which demonstrates the presence of insecurities typical of adolescence, but without a great predominance of feelings of worthlessness.

In the final graph, with the sum of each athlete's score, it was observed that all fell between average self-esteem (20 to 29 points) and high self-esteem (30 to 40 points). No cases of low self-esteem were identified.

These findings reinforce the importance of sports practice as a positive factor in the emotional and social development of adolescent girls.

GRAPHS AND QUESTIONS

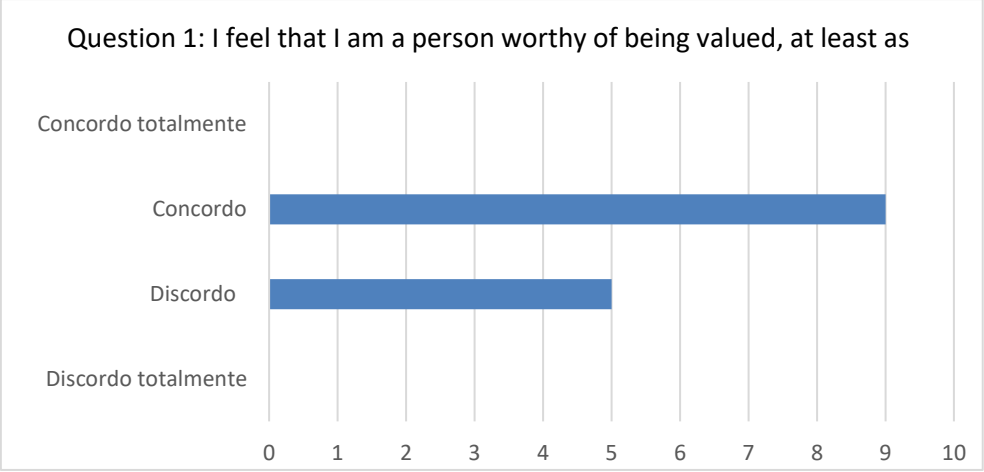


Chart 1: I feel that I am a person worthy of being valued, at least as much as others.

The results showed that most participants responded “agree” 9, while 5 stated “disagree”. No adolescents selected the options “strongly agree” or “strongly disagree”. This data indicates that a large proportion of adolescents recognize a certain personal value, but there is still a significant group that has insecurities regarding their own worthiness of appreciation.

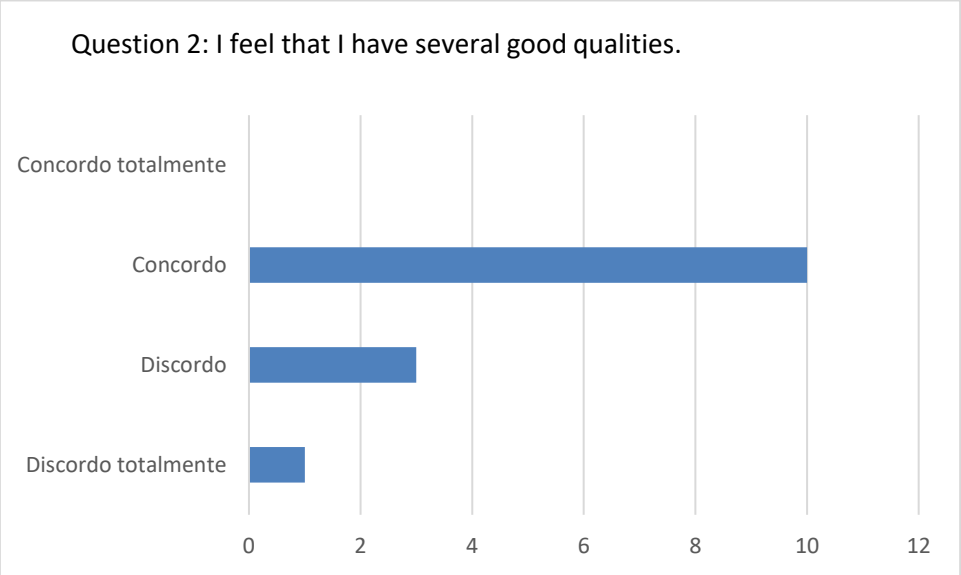


Chart 2: I feel I have several good qualities.

Most responded “agree” 10, while 3 marked “disagree” and 1 opted for “strongly disagree”. No teenager chose the alternative “strongly agree”. These results suggest that most young people recognize that they possess positive qualities, but there is still a portion that demonstrates difficulties in perceiving or valuing their own personal characteristics.

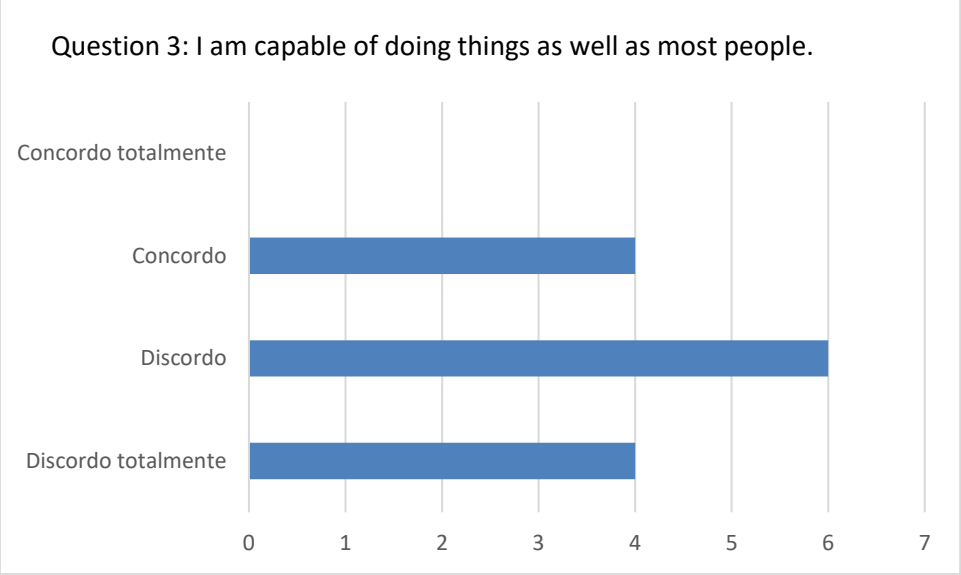
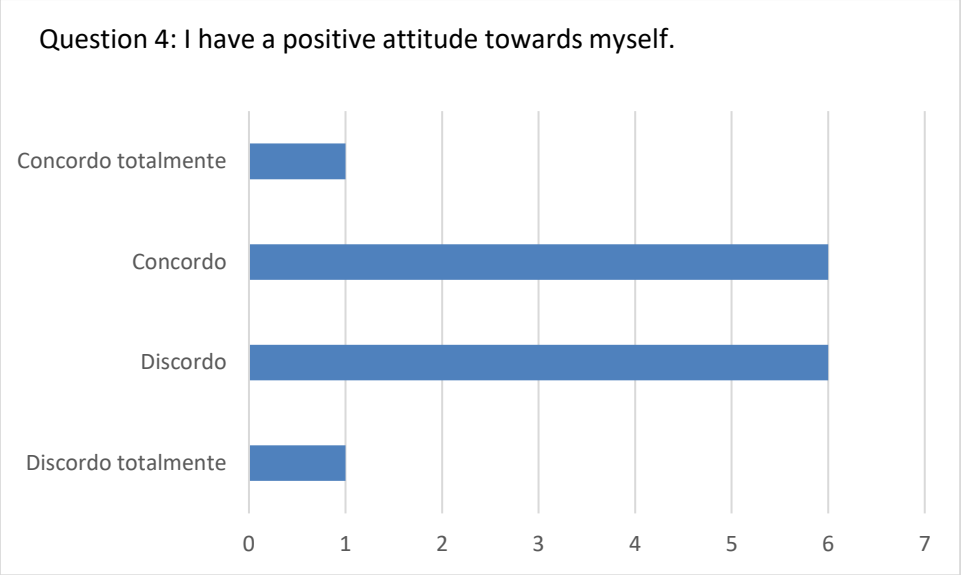


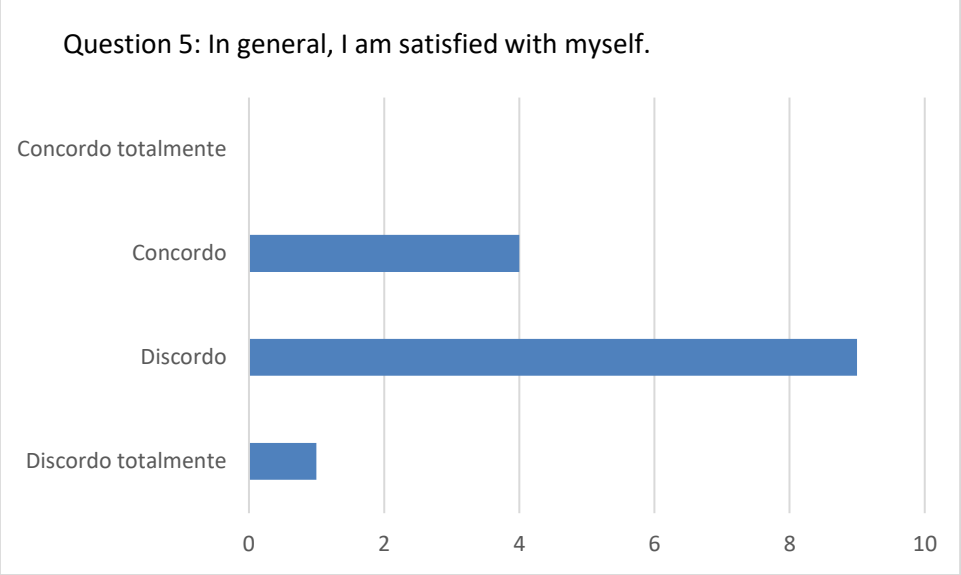
Chart 3: I am able to do things as well as most people.

The 14 teenage volleyball players presented responses that point to different levels of self-confidence. Only 4 participants marked "agree," while the majority revealed some difficulty in believing in their own abilities: 6 responded "disagree" and 4 marked "strongly disagree." No teenager selected the "strongly agree" option. These results show that a significant portion of young people have insecurities about their competence compared to others.



Graph 4: I have a positive attitude towards myself.

The volleyball players presented responses that were evenly distributed between positive and negative perceptions. 1 participant responded "strongly agree," 6 marked "agree," while another 6 opted for "disagree," and 1 chose "strongly disagree." This result shows that, although some young people demonstrate a favorable attitude towards themselves, there is also a significant portion that reveals difficulties in maintaining a positive attitude about their own image.



Graph 5: Overall, I am satisfied with myself.

Only 4 participants marked “agree,” while the majority demonstrated a negative perception: 9 responded “disagree” and 1 chose “strongly disagree.” No adolescent selected the “strongly agree” option. These results show that a large part of young people face difficulties in recognizing self-satisfaction, which can reflect on aspects of self-esteem and emotional well-being. The mother of athlete number 5 shared that, after starting volleyball training, she noticed significant changes in her daughter's behavior. She began to show more willingness to leave her room and interact with the family, reducing the time she spent on her cell phone. In addition, the athlete began to get more involved in school activities, even receiving praise from teachers for her performance and attitude. This account shows that sports practice has played a

motivating and positive role in the young woman's social and emotional development.

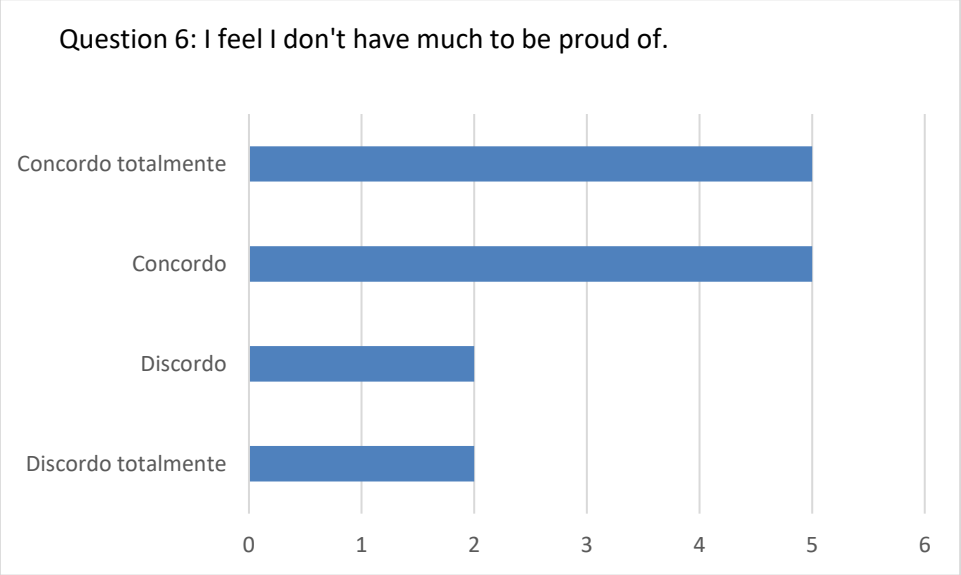


Chart 6: I feel I don't have much to be proud of.

The responses point to a considerable level of self-criticism. Most young people positioned themselves negatively in relation to their own worth: 5 marked "strongly agree" and 5 responded "agree". In contrast, only 2 indicated "disagree" and another 2 chose "strongly disagree". These results suggest that a significant portion of adolescents have difficulty recognizing reasons for personal pride, which may indicate weaknesses in the development of self-esteem.

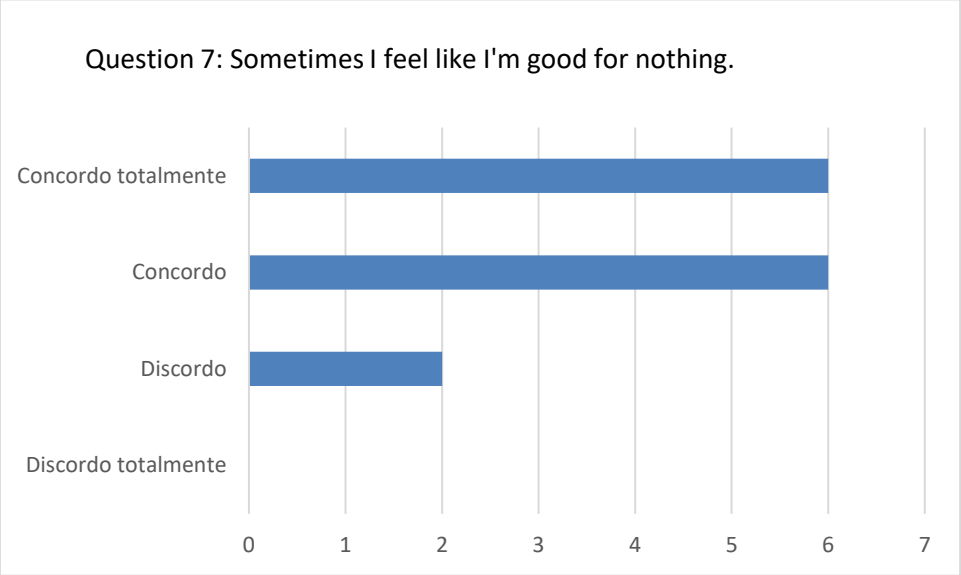
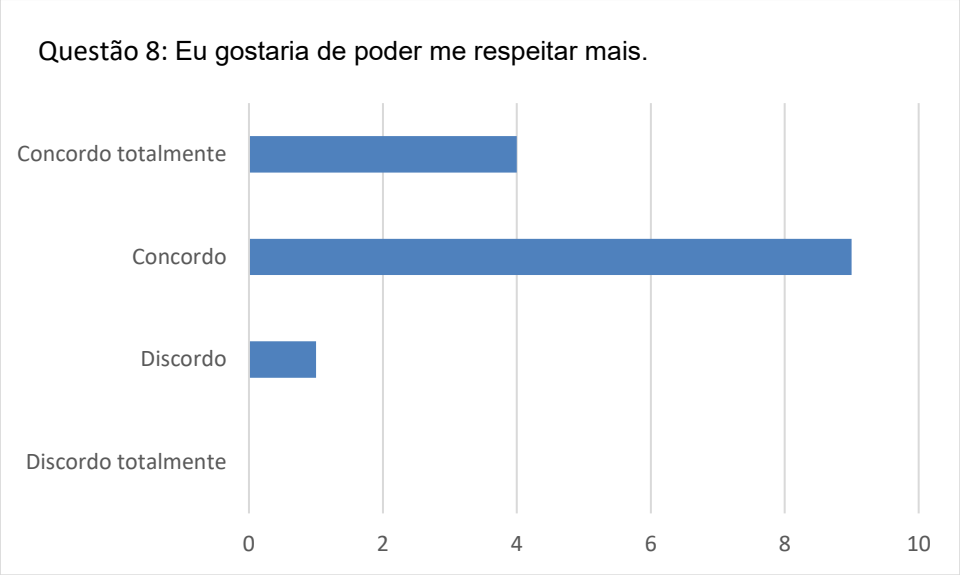


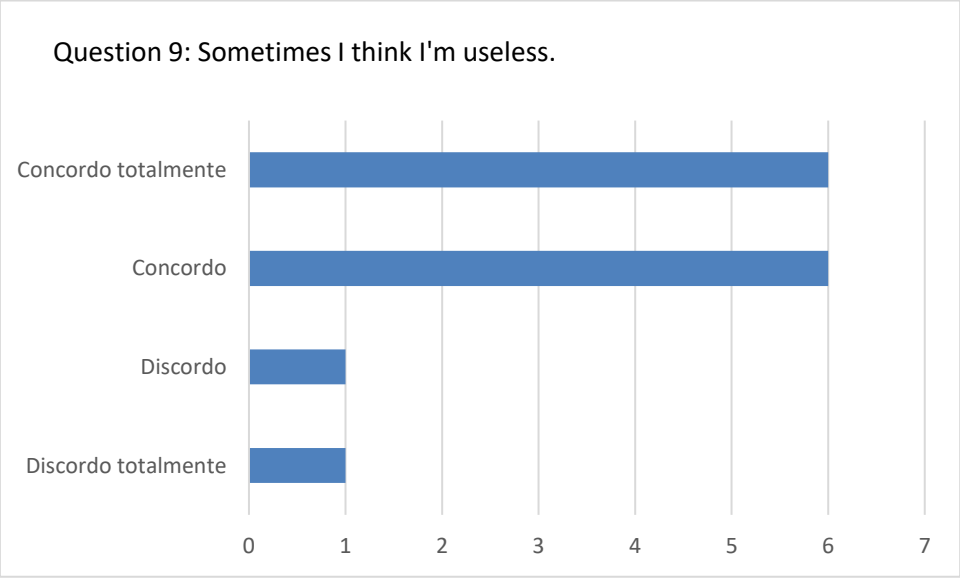
Chart 7: Sometimes I feel like I'm good for nothing.

The responses indicate a worrying level of self-deprecation. Six participants marked "strongly agree" and another six marked "agree," showing that the majority identify with the statement. Only two adolescents responded "disagree," and none selected "strongly disagree." This data suggests that many young people experience frequent moments of insecurity or self-deprecation, signaling a possible area of focus for strengthening self-esteem.



Graph 8: I wish I could respect myself more.

The vast majority agreed with the statement: 4 responded “strongly agree” and 9 marked “agree”. Only 1 adolescent chose “disagree”, while none selected “strongly disagree”. These results indicate that, despite recognizing some personal value, most young people feel the need to strengthen their self-respect, revealing weaknesses in the construction of self-esteem.



Graph 9: Sometimes I think I'm useless.

The responses reveal a high level of self-criticism. Most identified with the statement: 6 marked "strongly agree" and another 6 marked "agree." Only 1 adolescent responded "disagree" and 1 chose "strongly disagree." These results suggest that many young people face moments of self-devaluation, which can negatively impact their self-esteem and confidence in different aspects of life. During training, athlete number 3 shared a significant account of her personal experience: she said that since she started participating in the team's activities, she has felt included in an environment of coexistence and support. According to her, this feeling of belonging is something she did not experience in other contexts, such as at school or in other everyday situations. Training, therefore, has provided not only physical and technical development, but also a safe space to strengthen social relationships and self-esteem.

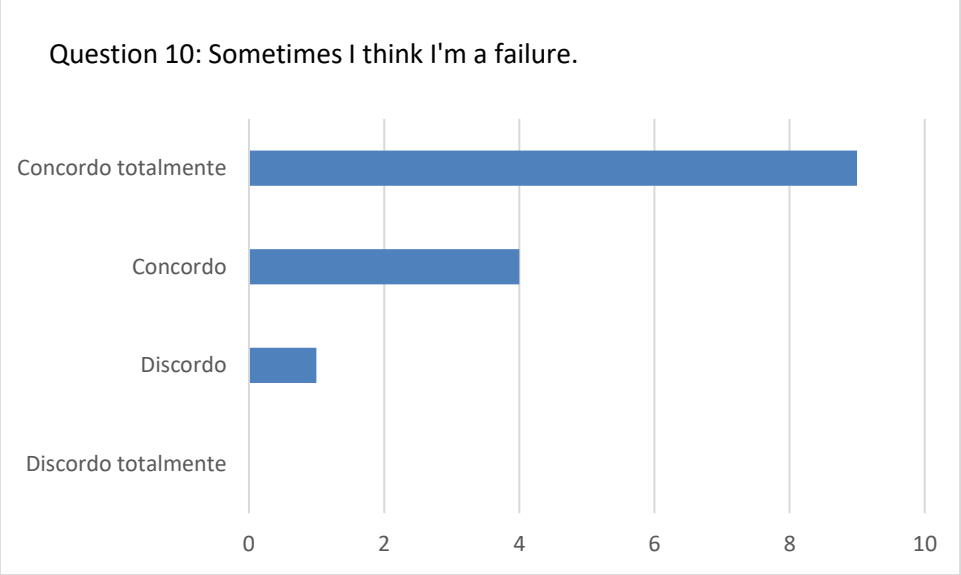


Chart 10: Sometimes I think I'm a failure.

Nine participants marked “strongly agree” and four marked “agree,” showing that the vast majority identify with the statement. Only one adolescent responded “disagree,” and none selected “strongly disagree.” These results indicate that many young people have frequent feelings of failure, pointing to weaknesses in self-esteem that can influence their emotional well-being and personal performance.

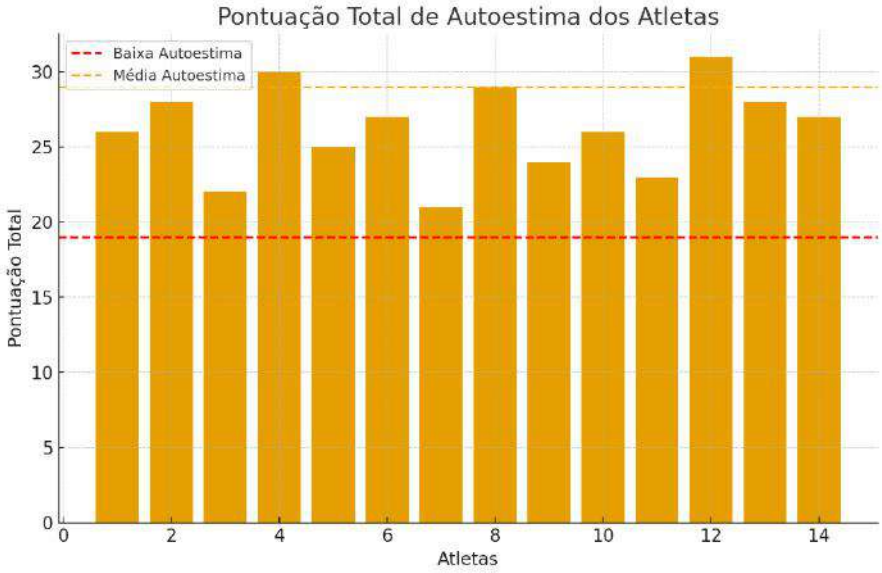


Chart 11: General Summary

The graph shows the distribution of total self-esteem scores of athletes assessed using the Rosenberg Self-Esteem Scale. It can be observed that most participants obtained scores in the medium to high self-esteem range, indicating a positive self-perception.

The findings of this study show that the adolescent girls (12–14 years old) participating in the volleyball initiation project have self-esteem levels ranging from "average" to "high," with no cases of low self-esteem. This pattern suggests that regular participation in team activities, such as volleyball, may be associated with a positive self-perception and increased self-confidence (according to the Rosenberg Self-Esteem Scale scores observed in this study).

These results align with a broad body of evidence linking sports participation, especially in team sports, to improved self-esteem and psychological well-being in young people. Recent reviews and observational studies demonstrate consistent associations between sports participation (especially team sports) and positive self-esteem/mental health in adolescents (DONALDSON; RONAN, 2012), as well as direct and indirect effects of sports participation via emotional intelligence and self-esteem (FERNANDES et al., 2024). For example, a recent systematic review pointed to general benefits of sports participation for mental health and social outcomes, highlighting potent effects when it comes to team sports. Longitudinal and cross-sectional studies have also recorded higher levels of self-esteem among physically active adolescents and participants in team sports.

In the Brazilian context, studies that have evaluated the applicability and psychometric properties of the Rosenberg Self-Esteem Scale in sports contexts indicate that the instrument presents good consistency and validity for use with athletes and practitioners of team sports. For example, Silva, Medi -Emanuel, Pesca & Cardoso (2021) found adequate construct validity and good internal consistency in a sample of athletes from team sports. Furthermore, the Dutch longitudinal study shows that team and non-aesthetic sports have a stronger association with self-esteem compared to individual or aesthetic sports (THE LONGITUDINAL ASSOCIATION, 2024) , which reinforces the reliability of the findings presented here.

- Specific comparison with other studies: Magnitude of the effect (absence of cases of low self-esteem): While many studies report a distribution in which the majority present medium/high self-esteem, some studies with larger samples and contexts of vulnerability indicate the occurrence of low levels in a portion of the participants. The complete absence of low cases in this study may reflect sample characteristics (regular project participants, with good attendance and institutional support) or selection bias (only available participants with consent). The study " *Participation in organized sport and self --esteem across adolescence"* shows that perceived competence acts as a mediator in this relationship between sports practice and self-esteem, which helps to explain differences in magnitude between samples with different characteristics (PERCEIVED SPORT COMPETENCE …, 2014).
- Team vs. Individual Sports: The literature often shows that team sports promote, in addition to physical fitness, psychosocial factors (co-authorship, belonging, social recognition) that positively influence self-esteem, something consistent with the volleyball results observed here. Recent reports

They highlight that, in girls, engagement in team sports tends to amplify gains in confidence and a sense of belonging.

- Possible mediating factors (experiences of success, social support, team identity): Research indicates that the positive effects of sports practice on self-esteem can be mediated by factors such as experiences of competence (success/mastery), support from coaches/peers, and the development of social skills. Recent studies have identified, for example, mediation by emotional intelligence and feelings of competence between sports participation and life satisfaction/self-esteem. These mechanisms offer plausible explanations for the high-average scores in the present study.

Limitations (compared to the literature)

- Sample size and generalization: The sample of 14 participants is small compared to population-based studies; therefore, the generalization of the results to other realities in the municipality or to other age groups is limited. Many comparative studies use larger samples and controls, allowing for more robust estimates. - Cross-sectional design: The cross-sectional design prevents causal inferences—that is, it is not possible to state whether the practice of volleyball caused average/high self-esteem or whether young people with higher self-esteem tend to participate in and persist in sports projects. Longitudinal studies show that positive effects tend to persist, but require follow-up over time for confirmation.
- Lack of a control group: Without comparison to non-practicing youth, it is difficult to estimate the incremental effect of local sports practice

compared to other contexts. Comparative studies usually include school controls to isolate the effect of sports.

- Limited sociodemographic characterization: Variables such as socioeconomic status, family support, and practice time can modulate self-esteem and were not detailed in a way that would allow stratified analyses, something that larger studies frequently investigate.

Practical implications and recommendations for future research: Maintaining and expanding sports programs: The results support the continuation and expansion of youth volleyball initiatives, especially due to their potential psychosocial benefits. However, programs should incorporate inclusion strategies and continuous evaluation.

Longitudinal studies with control groups: It is recommended to replicate the investigation with a larger sample, longitudinal design, and control group (or non-practicing school sample) to assess causality and the evolution of scores over time. Assess mediators and moderators: Investigating mediating variables (coach support, perception of competence, team cohesion) and moderating variables (socioeconomic level, body mass index, history of sporting success) will allow us to understand why and for whom sport works best. Attention to instrument validity: Continuing to use validated scales (adapted Rosenberg) and reporting indicators of internal consistency (Cronbach's α) improves comparability with national and international literature.

IV. CONCLUSION

The results demonstrate that the adolescent girls evaluated generally have average to high self-esteem, suggesting that playing volleyball has played a relevant role in strengthening self-confidence and a positive self-perception.

This outlook is encouraging, as self-esteem is directly associated with motivation, academic and athletic performance, and mental health. The absence of low self-esteem levels among the participants indicates that the sports project analyzed contributes not only to technical development in volleyball, but also to the promotion of psychological and social well-being.

It is therefore recommended that such initiatives be maintained and expanded, ensuring that more and more young people can experience sports that stimulate personal growth and individual development.

REFERENCES

[1] BARDIN, Laurence. *Content Analysis* . São Paulo: Edições 70, 2016.

[2] BOMTEMPO, José Vicente. *Sports pedagogy: from initiation to high performance* . Rio de Janeiro: Shape, 2001.

[3] CARVALHO, Marcos. *Sport and leisure in the community: the role of volleyball* . Belo Horizonte: EdUFMG, 2018.

[4] Brazilian Volleyball Confederation (CBV). *History of achievements of Brazilian volleyball* . Rio de Janeiro: CBV, 2020. Available at: https://www.cbv.com.br . Accessed on: September 29, 2025.

[5] COSTA, João Henrique. *School Volleyball: Fundamentals and Pedagogical Practice* . São Paulo: Cortez, 2016.

[6] CRUZ, Ronaldo Marcos de Souza et al. Evaluation of self-esteem in school adolescents using the Rosenberg Self-Esteem Scale. *Brazilian Journal of Education and Health* , v. 7, n. 1, p. 63–72, 2017.

[7] DONALDSON, S.; RONAN, K. A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. *International Journal of Behavioral Nutrition and Physical Activity* , vol. 10, no. 98, 2012.

[8] FERNANDES, HM; COSTA, H.; ESTEVES, P.; MACHADO RODRIGUES, AM; FONSECA, T. Direct and indirect effects of youth sports participation on emotional intelligence, self-esteem, and life satisfaction. *Esportes* , v. 12, n. 6, p. 155, 2024.

[9] FERREIRA, Lucas; LIMA, Patrícia. Physical benefits of volleyball practice in adolescents. *Brazilian Journal of Sports Sciences* , v. 42, n. 1, p. 55–62, 2020.

[10] FIVB – *Fédération Internationale de Volleyball* . *World Rankings and Historical Results* . Lausanne: FIVB, 2021. Available at: https://www.fivb.com . Accessed on: September 29, 2025.

[11] GIL, Antonio Carlos. *Methods and techniques of social research* . 7th ed. São Paulo: Atlas, 2019.

[12] LOPES, Ana Clara; MOURA, Felipe. Serbia's dominance in women's volleyball: an analysis of recent international competitions. *Brazilian Journal of Sport and Society* , v. 10, n. 3, p. 88–97, 2022.

[13] MARTINS, Cláudia Oliveira; FREITAS, Neuma Chaves de. Self-esteem of adolescents: contributions to nursing care. *Revista de Enfermagem da UFSM* , v. 12, p. 1–20, 2022.

[14] MARTINS, Cláudia Regina. Adaptations of volleyball for the elderly: inclusion and health. *Movimento & Saúde* , v. 18, n. 2, p. 40–47, 2022.

[15] OLIVEIRA, Maria Eduarda. *History and evolution of world volleyball* . Rio de Janeiro: EdUERJ, 2017.

[16] OLIVEIRA, Tainá; SANTOS, Gabriel. Sport as a tool in promoting public health. *Revista Saúde & Movimento* , v. 15, n. 3, p. 78–85, 2021.

[17] PARTICIPATION IN ORGANIZED SPORT AND SELF ESTEEM ACROSS ADOLESCENCE: The mediating role of perceived sport competence. *Perceived Sport Competence* , longitudinal study, 2014.

[18] PEREIRA, Ana Luiza et al. The influence of sport on the mental health of young people. *Revista Psicologia e Sociedade* , v. 32, n. 4, p. 99–107, 2020.
[19] ROSENBERG, Morris. *Society and the adolescent self-image* . Princeton: Princeton University Press, 1965.
[20] SAMULSKI, Dietmar. *Sports Psychology: Concepts and New Perspectives* . Barueri, SP: Manole, 2009.
[21] SANTOS, Carla Regina dos. *Team sports: a historical and methodological approach* . Belo Horizonte: Autêntica, 2015.
[22] SILVA, Dayane Fernanda da et al. Sports practice and self-esteem of adolescents. *Brazilian Multidisciplinary Journal* , v. 25, n. 1, p. 54–63, 2022.
[23] SILVA, Rafael; MENDES, Tiago. The spread of volleyball in Brazil: from the YMCA to professionalization. *Brazilian Journal of Physical Education and Sport* , São Paulo, v. 32, n. 2, p. 101–115, 2018.
[24] SILVA, Walan Robert da; MEDEIROS, Thiago Emannuel; PESCA, Andréa Duarte; CARDOSO, Fernando Luiz. Construct validity of Rosenberg Self-esteem Scale in Brazilian Athletic Context. *Revista Andaluza de Medicina del Deporte* , v. 14, n. 3, p. 171–175, set. 2021.
[25] SOUZA, Vinícius; ALMEIDA, Júlia. School volleyball: contributions to social and cognitive development. *Physical Education in Review* , v. 27, n. 1, p. 33–41, 2019.
[26] THE LONGITUDINAL ASSOCIATION BETWEEN SPORT PARTICIPATION AND SELF ESTEEM IN YOUTH IN THE NETHERLANDS: The role of sport type. *Journal of Science and Medicine in Sport* , vol. 28, no. 2, p. 140–146, 2025.
[27] WEINBERG, Robert S.; GOULD, Daniel. *Fundamentals of sport and exercise psychology* . 2nd ed. Porto Alegre: Artmed, 2001.
[28] YAMAMOTO, Hiroshi. *The Rise of Volleyball in Japan* . Tokyo: Nippon Sports Press, 2019.

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The Importance of Using Personal Protective Equipment (PPE) and Collective Protective Equipment (CPE) for Workers Exposed to Silica: An Updated Literature Review

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***Abstract*—** *This article aims to identify preventive measures for workers involved in mining activities, particularly those exposed to silica dust and at risk of developing silicosis, an occupational pulmonary disease that is progressive and irreversible. Mining environments contain various substances or products that pose health risks, including cement, rubber, wood, petroleum derivatives, epoxy resins, chromium, and nickel. Continuous exposure to these agents requires the implementation of control strategies, including respiratory protection measures, environmental monitoring, and occupational health actions, aiming to minimize occupational risks and prevent the onset of pneumoconioses. The role of the Specialized Service in Safety Engineering and Occupational Medicine (SESMT) is essential for risk identification and classification, as well as for defining the appropriate types of personal protective equipment (PPE) required for each job and sector. Periodic workplace inspections and health monitoring allow functional adjustments whenever changes are detected that may compromise workers' physical integrity. These measures also include continuous education and training on proper PPE use, emphasizing the importance of each device as a protective tool: "any device or product, for individual use by the worker, intended to protect against risks likely to threaten work safety and health" (BRAZIL, 1978). The effectiveness of preventive measures depends on multidisciplinary work involving safety, engineering, and occupational health professionals. Integration among these sectors not only reduces risks but also enables the implementation of continuous, evidence-based prevention actions. According to studies, applying knowledge from safety engineering and occupational medicine to all components of the work environment, including machinery, equipment, and processes, contributes to the elimination or reduction of health risks for workers (HAAG, 2001). The methodology adopted in this study consisted of a bibliographic review, including the analysis of scientific articles, specialized journals, technical literature, and regulatory standards (NR), aiming to understand occupational silica exposure, prevention mechanisms, and the role of occupational health and safety policies. This approach allowed*

the identification of effective strategies for silicosis prevention, highlighting the importance of inspection, periodic health monitoring, and proper PPE training. In conclusion, reducing the incidence of silicosis depends on a combination of engineering controls, individual protection, periodic medical follow-up, and worker awareness. Integration among SESMT, health professionals, and industrial managers is essential for implementing consistent and sustainable preventive actions, ensuring not only the protection of workers' health but also the maintenance of productivity and safety in mining environments.

I. INTRODUCTION

Silicosis is a chronic, irreversible, and progressive occupational lung disease, classified as a pneumoconiosis caused by the inhalation of respirable crystalline silica (SLC) particles. This pathology is characterized by the development of a persistent inflammatory process, granuloma formation, and subsequent pulmonary fibrosis, resulting in functional impairment and a significant reduction in the quality of life of the exposed worker (RIBEIRO et al., 2023).

Despite advances in occupational health, silicosis remains a serious public health problem, especially in developing countries, where mining, construction, and, more recently, the manufacture of artificial stone countertops represent significant sources of exposure (SBPT, FUNDAÇÃO JORGE DUPRAT FIGUEIREDO, 2024). In Brazil, recent outbreaks have drawn the attention of health authorities, highlighting the persistence of shortcomings in prevention and workplace monitoring strategies.

From a pathophysiological point of view, silica inhalation triggers the activation of alveolar macrophages, which, upon phagocytizing the particles, release inflammatory and pro-fibrotic mediators, such as tumor necrosis factor alpha (TNF-α) and interleukins. This inflammatory cascade results in the deposition of collagen fibers and thickening of the lung parenchyma, with a consequent reduction in ventilatory capacity (LOMBARDI et al., 2023).

Recent literature has highlighted the importance of inflammatory biomarkers in the early detection of silicosis, such as lactate dehydrogenase (LDH) and soluble TNF receptors (sTNFRII), which show a direct correlation with the clinical and radiological severity of the disease (RIBEIRO et al., 2023). Furthermore, genetic studies demonstrate that individual susceptibility is a determining factor in the evolution of silicosis, since polymorphisms in genes related to the inflammatory response and oxidative stress directly influence clinical severity, even among individuals subjected to similar exposures (COSTA et al., 2024).

The clinical forms of silicosis include chronic silicosis, which develops after decades of continuous exposure, accelerated silicosis, associated with intense exposures over a period of 5 to 10 years, and acute silicosis, also known as silicoproteinosis, which develops within a few months to years and progresses rapidly, often culminating in severe respiratory failure (MSD MANUAL, 2024). All these forms share the common characteristic of being incurable, with prevention being the only effective way to reduce incidence.

Recent cases of silicosis among workers in the artificial stone industry have prompted the publication of warnings by the Brazilian Society of Pulmonology and Phthisiology and Fundacentro, which highlighted the severity of the disease and the historical negligence in collective and individual protection measures (SBPT, FUNDAÇÃO JORGE DUPRAT FIGUEIREDO, 2024). Furthermore, accounts from patients and healthcare professionals have been presented in documentaries that expose the reality of the industry and its social and human impacts.

The epidemiological relevance of silicosis in Brazil is evidenced by notifications concentrated in mining regions, such as Minas Gerais, and in ornamental rock processing centers, such as Espírito Santo. Recent data indicate that the lack of continuous surveillance and deficiencies in occupational monitoring contribute to late diagnosis, when the disease is already in an advanced and irreversible stage (BEZERRA et al., 2022).

Given this scenario, silicosis is not only a health problem, but also a social, legal, and economic challenge. Affected workers suffer severe functional limitations, reduced work capacity, and increased dependence on health and social security systems. Therefore, a thorough understanding of its pathophysiological mechanisms, contemporary epidemiology, and prevention strategies is fundamental to reducing the impact of the disease.

In this context, the present research aims to present a review on silicosis, highlighting its clinical, pathophysiological, genetic, and epidemiological aspects, based on recent studies, seeking to emphasize the importance of surveillance and prevention as the main strategies in addressing this occupational pathology.

Silicosis is an occupational pneumoconiosis caused by the inhalation of dust containing crystalline silica, characterized as an irreversible inflammatory and fibrosing disease with variable progression. Despite being widely known, it remains a serious global public health problem, impacting millions of exposed workers in different industrial sectors (GBD, 2023).

It is estimated that approximately 230 million people are occupationally exposed to respirable silica worldwide, with more than 30 million in China and India alone, revealing the epidemiological magnitude of the disease (DISCOVER PUBLIC HEALTH, 2025). Data from the Global Burden of Disease indicate that, between 1990 and 2019, the absolute number of cases increased by 64.6%, although standardized incidence and mortality rates have decreased in some countries (GBD, 2023).

In Brazil, silicosis is considered the most prevalent pneumoconiosis, mainly in mining, ornamental stone processing, and civil construction regions (SOUZA, MONTEIRO, 2025). An epidemiological study indicates a prevalence of 37% among workers in semi-precious stone mining, associated with risk factors such as inadequate ventilation and dry drilling (ALGRANTI et al., 2021).

Regarding mortality, analysis of the last few decades revealed an increasing trend until the mid-2000s, followed by a decline, especially in areas with greater enforcement of workplace safety standards (ALGRANTI et al., 2021). Even so, recent estimates indicate that, in 2018, approximately 3 million formal Brazilian workers were exposed to silica, representing more than 1% of the economically active population (JBP, 2025).

The impacts of silicosis transcend the clinical sphere, affecting socioeconomic dimensions. The disease frequently affects individuals of working age, reducing their ability to work and increasing costs related to medical and social security care. Furthermore, its irreversibility reinforces the importance of epidemiological surveillance and prevention as central strategies to mitigate its effects (DISCOVER PUBLIC HEALTH, 2025).

Thus, the epidemiology of silicosis reveals a persistent condition, with significant growth in the absolute number of cases, especially in developing countries. In Brazil, despite a relative reduction in mortality in some periods, the high prevalence and widespread occupational exposure highlight the disease's continued impact. In this sense, public policies for control and monitoring are fundamental to reducing the clinical and social burden of silicosis.

Silica, or silicon dioxide, is a natural compound composed of two chemical elements in the Earth's crust: oxygen and silicon. It is found in nature in amorphous and crystalline forms, which, when combined with metals and oxides, give rise to silicates such as talc, feldspar, kaolin, and mica. The amorphous form, although not inert, is less toxic than the crystalline form, and is found in vitrified volcanic rocks, unheated diatomaceous earth, silica gel, synthetic glass, and glass wool. (TERRA FILHO, 2006)

Inhalation of silica dust is associated with the occurrence of silicosis, an occupational chronic obstructive pulmonary disease, lung cancer, and diffuse interstitial fibronodular lung disease, caused by the inhalation of crystalline silica. It is the leading cause of disability among occupational respiratory diseases. (SANTOS, 2010)

Known since Antiquity, it was Visconti, in 1870, who first applied the term silicosis, but it had already been described in mummies from ancient Egypt and Greece. Hippocrates also described it when analyzing respiratory difficulties in metal diggers, and it was described in the 16th century in Bohemian miners and in stonecutters in the 18th century. (SANTOS, 2010).

How can we reduce accidents and occupational illnesses among workers exposed to silica?

There are recorded instances, dating back approximately two thousand years, of workers using masks to protect themselves from silica dust, which was considered hazardous. It was observed that the mixture of dust with air caused lung damage.

Thus, humidification and ventilation inside mines reduce the amount of dust in the air, recognized as an agent of pulmonary diseases, and coughing and dyspnea are common in certain mines.

Given this context, the following objectives were proposed:

- To present a literature review on the importance of using individual and collective protective equipment, the profile of the exposed worker, to determine if silicosis occurs even with the use of PPE, to identify shortcomings in accident prevention measures, to identify preventive measures for silica workers located in a hazardous environment.

The rationale for developing this work is based on providing more information about silicosis, an occupational lung disease in mining workers. The proposed objective and methodology adopted were a bibliographic research approach, the research sources for this work were journals, articles, specialized literature in the field, and regulatory standards (NR).

II. MATERIALS AND METHODS

For the development of this study, bibliographic research was chosen, which encompasses secondary sources and bibliography already made public in relation to

the study topic, from individual publications, bulletins, newspapers, magazines, books, research, monographs, theses, cartographic material, among others, to even oral means of communication: radio, magnetic tape and audiovisual recordings, films and television.

The purpose of the broad scope of the selected sources was to update readers interested in this subject and to familiarize them with the various types of individual and collective protective equipment used in the treatment of silicosis.

The results were based on questions raised by the various sources researched.

III. DEVELOPMENT

Silica

Silica, composed of silicon dioxide (SiO_2) , is an abundant mineral in the Earth's crust and is present in rocks, sands, and clays, being widely used in industrial processes such as ceramics, construction, cosmetics, and pharmaceuticals (INCA, 2022). The respirable crystalline form, when inhaled, represents a significant occupational risk by triggering serious respiratory diseases.

Globally, it is estimated that approximately 230 million workers are exposed to respirable silica dust, with 34 million of these working in China and India, the countries with the highest prevalence, reinforcing the epidemiological relevance of silica as an occupational risk (DISCOVER PUBLIC HEALTH, 2025). Studies from the Global Burden of Disease highlight that silicosis represents 90% of pneumoconiosis cases worldwide, with increasing trends in terms of the absolute burden of the disease (incidence and DALYs), although some standardized rates may show a decline (GBD, 2023).

In Brazil, occupational exposure to silica is significant and concentrated in sectors such as civil construction, stone extraction, non-metallic minerals, and metallurgy. In 2001, 5.6% of Brazilian workers were classified as "definitely exposed" to silica, a percentage higher than that observed in European countries (REIS, 2008). The mining of semi-precious stones, especially in cooperatives in the South of the country, showed a prevalence of silicosis of up to 37% among active workers (ALGRANTI et al., 2021).

Furthermore, recent exposures in the artificial stone industry have generated global concerns, with an increase in cases, warnings from health authorities, and evidence of high concentrations of silica dust emitted during cutting and polishing (FUNDACENTRO, 2024). Silica also presents adverse effects that go beyond silicosis, including lung cancer, autoimmune diseases, and tuberculosis, making it a multifaceted agent of concern in occupational health (INCA, 2022).

Furthermore, recent studies in China have estimated that, over 30 years, the cumulative incidence of silicosis can reach 50–57% among workers exposed to total and respirable dust (JMIR PUBLIC HEALTH, 2024). This evidence highlights the urgent need for more effective preventive measures and regulatory policies to control silica exposure.

Therefore, silica, although ubiquitous in natural resources and industrial products, represents a serious and persistent occupational risk. Its widespread presence requires continuous vigilance, strict regulation, and the adoption of environmental control technologies. Recognizing its systemic impacts and implementing preventive strategies are imperative to reduce this burden on workers and health systems.

Chronicle

The chronic form is the most common, known as the simple nodular form, and occurs after many years of exposure to relatively low levels of dust. According to ZISKIND, 1976, it can last from ten to twenty years at very low dust levels. It is characterized by the presence of small, scattered nodules, less than one centimeter in diameter, which are prevalent in the upper thirds of the lungs. Histology shows nodules with concentric layers of collagen and the presence of light-polarized structures. As the disease progresses, the nodules may coalesce, forming larger conglomerates and replacing the lung parenchyma with collagenous fibrosis. Patients are usually asymptomatic or present with symptoms that are preceded by radiological changes. (BRUNNER & SUDDARTH, 1998)

Dyspnea on exertion is the main symptom, and the physical examination usually does not show significant changes in the respiratory system. This type of silicosis can be observed in the ceramics industry. (BRUNNER & SUDDARTH, 1998)

Accelerated

Accelerated or subacute silicosis is a clinical term applied to a condition that has an intermediate rate of progression between acute silicosis and classic chronic nodular disease, requiring, on average, five to ten years of dust exposure for the appearance of radiological changes. According to ZISKIND, 1976, the symptoms are similar to those of the chronic form, but its development occurs in earlier stages, with an intense interstitial inflammatory component and cellular desquamation in the alveoli. (CANEIRO, 2003)

Respiratory symptoms are usually early and limiting, with a high potential for progression to the complicated form of the disease, such as the formation of conglomerates and massive fibrosis, this silicosis is observed in well diggers. (BRUNNER & SUDDARTH, 1998)

Acute

The acute form of the disease is very rare and occurs in workers exposed to exceptionally high concentrations of fine, recently fractured crystalline silica particles, as occurs in sandblasting and stone grinding. (FERREIRA, 1999)

Dyspnea can be debilitating, potentially leading to death from respiratory failure, accompanied by a dry cough and compromised general condition. Physical examination reveals diffuse crackles, and the radiological pattern differs significantly from other forms, characterized by diffuse and progressive alveolar infiltrations, often accompanied by poorly defined nodules. (HAAG, 2001)

Diagnosis

Diagnosing silicosis requires a rigorous clinical approach, especially in occupational environments with exposure to respirable crystalline silica (CLS), such as mining, construction, and artificial rock industries. The central focus of the diagnosis is a detailed occupational history, which should include the nature, intensity, and duration of exposure, as well as the use of protective measures (MSD, 2025).

The physical examination and symptoms, even if nonspecific, such as dyspnea, dry cough, and fatigue, should be associated with appropriate diagnostic procedures to avoid late diagnoses, which are common in Brazilian clinical practice (Fundacentro, 2024).

Chest radiography remains a primary screening tool, as it combines images with occupational history in most diagnoses. Observed radiological patterns include the presence of nodules and linear shadows in the middle and upper zones, or, in cases of complicated silicosis, fibrous conglomerates migrating towards the pulmonary hilum (Brazilian Radiology, 2025).

When radiography is inconclusive or in cases considered "borderline," high-resolution computed tomography (HRCT) is indicated. A study with former gold miners used clinical and environmental criteria to define a flowchart that guides the indication for HRCT, highlighting its usefulness in the early detection and silent severity of the disease (UFMG, 2024).

The correlation between radiological and anatomopathological findings reinforces the role of HRCT. Patterns such as confluent nodules or conglomerate masses, especially in the upper posterior thirds of the lungs, have been described as typical of silicosis.

Spirometry and pulmonary function tests, including diffusive carbon monoxide capacity (DLCO), provide important functional data. Restrictive changes or reduced gas exchange confirm the functional impact of the disease and help differentiate silicosis from other lung diseases (MSD, 2025).

The application of artificial intelligence (AI) technologies in diagnostic imaging is a promising frontier. A model based on graphical transformers combined with neural networks achieved very high accuracy in distinguishing between silicosis and pneumonia, with an F1 score of 0.9749 and an AUC greater than 0.99, in a recent deep learning study (Bui et al., 2024).

Furthermore, South Africa plans to incorporate AI for screening and diagnosing silicosis and tuberculosis in miners, aligning with WHO recommendations and recognizing the role of radiography as a basis, but expanding its efficiency through technology (South Africa, 2024).

In general, the ideal diagnosis of silicosis should combine: occupational history, suggestive clinical symptoms, radiography as an initial examination, HRCT for borderline cases, functional tests to assess severity, and, if available, access to AI applied to radiology for greater diagnostic accuracy.

Finally, mandatory notification mechanisms and active surveillance are essential. Early identification and establishment of causal links enable more successful preventive interventions, interrupting chains of exposure and contributing to public health strategies (Fundacentro, 2024).

The diagnosis of silicosis is made using chest radiography, along with a coherent clinical and occupational history. However, other procedures are also necessary. (FUNDACENTRO, 2011)

Lung biopsy is authorized in the presence of radiological changes with a lack of occupational history data suggesting an association. In these cases, it can contribute to the diagnosis of another disease, confirm an atypical presentation (e.g., diffuse, non-granulomatous fibrosis), or even differentiate it from chronic beryllium disease, whose etiological diagnosis has implications for treatment. (TERRA, 2006)

Simple chest radiography remains the highest quality and most effective instrument for regular and repeated monitoring of exposed workers, given its low cost and low radiation dose. (OCCUPATIONAL SAFETY

AND HEALTH, 2002)

According to the new edition of the International Classification of Radiographs of Pneumoconiosis of the International Labour Organization, 2000 revision, with minor modifications compared to the 1980 revision, the importance of this examination in medical control programs for exposed populations is ratified. Furthermore, an international investigation into the use of digital chest radiography is underway, and there is consensus among experts in the field that high-resolution computed tomography of the chest, despite its greater sensitivity in some situations, should not become a monitoring examination, precisely because it has low competitiveness in the two aspects mentioned above: cost and radiation dose.

Control Measures

Monitoring dust production in the workplace can help prevent silicosis. When this cannot be controlled, as might be the case in the sandblasting industry, workers should wear masks that provide clean outside air or that completely filter out the particles. This protection may not be available to all workers in a dusty area (e.g., painters and welders), and in that case, abrasives other than sand should be used whenever possible. According to SITICECOM, workers exposed to silica dust should have regular chest x-rays, every six months for those working with sandblasting and every two to five years for the rest, so that any problems can be detected as early as possible. If the x-ray diagnoses silicosis, the doctor will advise the worker to avoid constant exposure to silica. Basically, the necessary prevention includes:

Personal Protective Equipment - PPE

Personal Protective Equipment (PPE) consists of essential devices for protecting the health and physical integrity of workers, especially in work environments that present occupational risks. According to Regulatory Standard NR-6 of the Ministry of Labor and Employment, PPE is considered to be any device for individual use, manufactured domestically or abroad, intended to protect the health and physical integrity of the worker, and which has a Certificate of Approval (CA) issued by the competent authority.

The effectiveness of PPE is directly related to its correct use and suitability to the type of risk present in the work environment. Studies indicate that adherence to the use of PPE can be influenced by factors such as comfort, training, and worker awareness. For example, research conducted by Silva et al. (2024) points out that the lack of adequate training is one of the main factors contributing to the non-use of PPE among healthcare professionals.

Furthermore, technological advancements have enabled the development of more efficient and comfortable PPE. Innovations such as thermal sensors and remote monitoring systems have been incorporated into PPE, aiming to increase the safety and well-being of workers. A recent study by Barros et al. (2024) presents the development of a low-cost thermal imaging sensor for industrial safety, applicable in Industry 5.0 and collaborative robotics, with high precision in detecting human presence.

In Brazil, the inspection and regulation of PPE (Personal Protective Equipment) are the responsibility of the Ministry of Labor and Employment, which establishes standards and procedures for the evaluation, certification, and commercialization of these devices. Ordinance No. 11,347, of May 6, 2020, establishes the procedures and technical requirements for the evaluation of PPE and the issuance, renewal, or alteration of the Certificate of Approval (CA), aiming to guarantee the quality and safety of products available on the market.

In summary, PPE plays a crucial role in preventing accidents and occupational diseases. Its effectiveness depends not only on the technical quality of the devices, but also on the awareness, training, and commitment of workers and employers to safety practices in the workplace.

Personal protective equipment (PPE) is mandatory in work situations where occupational hazards are not fully controlled at the source of generation and transmission.

Personal protective equipment (PPE) must be provided free of charge by the company and be certified by the competent body responsible for certifying this type of equipment, as stipulated in occupational safety and health legislation.

Respiratory protective equipment (RPE) must be used by workers in the ceramic tile manufacturing process until engineering and general measures are sufficient to keep dust concentrations in the work environment below the action level (AL), which is defined as half the recommended Occupational Exposure Limit (OEL), and should be mandatory in maintenance activities.

The filters for respiratory protection equipment (RPE) must be specified according to the characteristics of the dust, considering the size, composition, and toxicity of the particles and the concentrations present in the work environment (Respiratory Protection Program, FUNDACENTRO). For dusts containing crystalline silica, the following categories may be indicated, according to these characteristics:

- Full-face respirator with P2 or P3 filter,

- Half-facepiece respirator with P2 or P3 filter,

- PFF2 or PFF3 filtering half-facepiece respirator (disposable mask).

The prescription and use of respiratory protection equipment must meet all the requirements of the Respiratory Protection Program (RPP), regulated by legal standards.

Personal Hygiene

In addition to using respiratory protection equipment, workers should be instructed and provided with the means to maintain personal hygiene and protect themselves from secondary sources of dust exposure, with measures such as:

- Wear work clothes preferably provided and laundered by the company,

- Separate work clothes from everyday clothes. To do this, the company must have changing rooms with double lockers for each worker,

- Do not use compressed air to clean clothes, as this procedure, in addition to exposing you to dust, poses other health risks.

Wash your hands, arms, and face before eating,

- to eat in an appropriate location separate from the production area,

- No smoking, preferably. If the worker is a smoker, they should smoke in a designated area, outside the production area,

- Do not wear a beard or mustache when using respiratory protection equipment.

Collective Protective Equipment - CPEs

What are PPEs? They are equipment installed in the workplace, which can be fixed or mobile, that serve to preserve the physical integrity and health of one or more workers at the same time and are used to prevent and/or minimize accidents.

Workplace Cleaning

Workplace cleaning should be done regularly, considering all areas where people circulate, including corridors, platforms, stairs, workshops, and rooms, as well as all process installations such as machinery and equipment, structures, and piping that may accumulate dust. Temporary or permanent storage areas should also be considered. (SITICECOM)

As a primary standard for cleaning production areas, it is essential that the design of the central industrial ventilation system considers its use for dust extraction during cleaning processes, through connection points for flexible hoses to the ducts, especially in press and mill areas and along enameling lines.

To vacuum up large spills of powdered material, ducted systems must be specifically designed for this purpose, in order to avoid loss of effectiveness in the central ventilation system.

In areas where forklifts and workers circulate around production lines, cleaning should preferably be done with self-propelled exhaust and/or floor washing carts. In situations where wet cleaning or exhaust methods are not technically feasible, other cleaning and collection resources, such as squeegees, shovels, and transport containers, should be used to generate the least possible dust dispersion. The use of sawdust, with biodegradable oil or another product for anointing the sawdust and deposited dust, must consider the proper disposal of waste and the risks it may pose to workers handling this waste and the cleaning products used, as well as its potential damage to the natural environment.

In locations where wet cleaning methods are used, ensure that electrical installations are properly protected from contact with water.

Equipment Maintenance

Maintenance operations may present special risk conditions, and all control measures should be adopted to minimize dust generation and worker exposure. The use of respiratory protection should be mandatory in situations where dust generation cannot be adequately controlled at its source.

Periodic checks and maintenance should be carried out on process equipment according to the instructions of its manufacturers and suppliers to ensure efficient operation, especially of enclosure and industrial ventilation systems.

Signaling

Workplace signage should be provided using warning and informational posters to inform workers about the risks present in the processes, the effects of exposure to these risks, and to guide them on preventive measures.

Warning signs can be used in areas with silica-containing dust.

In addition to warning posters about the risks present in work environments, posters with content that provides guidance, in particular, on the control measures to be observed to avoid the generation of and exposure to dust are recommended.

IV. FINAL CONSIDERATIONS

Silicosis remains one of the most relevant occupational pneumoconioses worldwide, caused by the prolonged inhalation of respirable crystalline silica particles. Recent studies show that occupational exposure remains significant

in sectors such as mining, construction, artificial rock industry, and metallurgy. Epidemiological data indicate that, even with labor regulations and preventive measures, there are still emerging cases among young workers, highlighting the need for continuous and rigorous monitoring of working conditions.

International reports indicate that the disease burden attributed to silicosis remains high, especially in developing countries where industrial safety practices may be insufficient. The prevalence of silicosis and the increase in associated morbidity reinforce the importance of integrated prevention strategies, including the correct use of personal protective equipment, the adequacy of industrial processes, and public occupational health policies.

Imaging studies are considered essential for the early diagnosis of silicosis, allowing the identification of pulmonary changes before the onset of severe clinical manifestations. Chest radiography remains the most widely used screening tool, while high-resolution computed tomography has demonstrated greater sensitivity in detecting nodules and early fibrosis. Recent research also indicates that the application of artificial intelligence in imaging exams can significantly increase diagnostic accuracy, allowing the differentiation of silicosis from other interstitial lung diseases.

Pulmonary function should be monitored periodically, as restrictive changes and decreased pulmonary diffusion reflect disease progression and functional impairment in patients. Clinical trials and systematic reviews highlight that the association between inflammatory biomarkers and genetic alterations can contribute to the assessment of individual risk and susceptibility to the disease, paving the way for personalized approaches to prevention and clinical follow-up.

Ongoing education and training for workers exposed to silica are fundamental to ensuring adherence to preventive measures. The implementation of occupational health programs, coupled with periodic inspections and safety audits, has demonstrated a reduction in the incidence of new cases. Furthermore, the systematic registration and reporting of cases allows for the construction of robust epidemiological databases, essential for trend analysis and the formulation of effective public policies.

Despite advances in understanding the pathophysiology of silicosis, significant gaps remain regarding the mechanisms that determine disease progression and the interaction between genetic, immunological, and environmental factors. Experimental studies suggest that silica particles can induce chronic inflammatory responses, leading to irreversible pulmonary fibrosis, but more research is needed to develop targeted therapies that can slow or halt this process.

Silicosis prevention should be considered a public health priority, taking into account not only individual clinical impacts but also the social and economic repercussions resulting from work disabilities and premature mortality. Integrated strategies combining process engineering, environmental control, the use of PPE, and periodic medical surveillance are fundamental to reducing occupational risk and promoting safe work environments.

In conclusion, silicosis remains a significant challenge to occupational health, requiring ongoing efforts in prevention, early diagnosis, and clinical follow-up. A comprehensive understanding of risk factors, coupled with the implementation of effective public policies and technological innovation, is essential to reduce the incidence of the disease and minimize its impacts on workers and health systems. Recent studies reaffirm that the combination of preventive measures, education, and rigorous monitoring constitutes the most effective strategy to address this pneumoconiosis and promote occupational health and safety in a sustainable manner.

This study, based on bibliographic research, found that there is no curative treatment for silicosis, and prevention is of great importance. It is recommended that employees exposed to this risk make mandatory use of PPE (Personal Protective Equipment), as per NR 22 (Brazilian Regulatory Standard 22).

Effective standards and controls are necessary for this to happen, ventilation and humidification processes must be adequate and tested periodically by determining the environmental concentration of harmful agents.

Given the possibility of contact with highly toxic substances, accident prevention must be rigorous, occupational medicine must always be concerned, and facilities for immediate medical care must be provided.

When it is not possible to reduce pollutants, sources of air from outside the work environment should be provided, replacing a potentially harmful substance with another that is harmless to the established occupational lung disease.

Moving the worker out of an environment exposed to silica may help slow the progression of the disease.

According to RUESCAS (2000), "there is no curative treatment, the only thing to do is to try to discover the condition early in order to change the activity of the affected worker, if there is still time, or retire him before he becomes disabled."

Protective equipment such as masks, respirators, and hoods should be used as a preventive measure. If collective

protection measures are insufficient, they should be carefully selected for specific sectors or functions. Workers must be properly trained in their use. Masks must be of good quality and appropriate for the exposures, with chemical or dust filters specific to each substance handled. Filters should be changed according to the manufacturer's recommendations.

REFERENCES

[1] ALGRANTI, E. et al. Mortality from silicosis in Brazil: temporal trends in the period 1980–2017. *American Journal of Industrial Medicine* , vol. 64, no. 3, p. 197-206, 2021. DOI: 10.1002/ajim.23215.

[2] BARROS, R. et al. Low-cost thermal imaging sensor for industrial safety in Industry 5.0 and collaborative robotics. *arXiv* , 2024. Available at: https://arxiv.org/abs/2410.23377 . Accessed on: September 10, 2025.

[3] BEZERRA, TRG, PALACIOS, MRR, GONÇALVES, KM, SILVA, AB Silicosis: an integrative review on the diagnosis, prevention, and clinical management of an occupational pneumoconiosis. *Revista FT* , v. 2, n. 1, p. 1-14, 2022.

[4] BOUI, BQ et al. Innovative Silicosis and Pneumonia Classification: Leveraging Graph Transformer Post-hoc Modeling and Ensemble Techniques. *arXiv* , 2024. Available at: https://arxiv.org/abs/2501.00520 . Accessed on: September 10, 2025.

[5] CANEIRO, APS, ALGRANTI, E. Fundacentro Silica and Silicosis Portal. São Paulo, 2003. Available at: https://www.fundacentro.gov.br. Accessed on: April 3, 2006.

[6] COSTA, LC et al. Silicosis: relationship between genetics, susceptibility and clinical severity. In: OLIVEIRA, SC (Org.). *Occupational Diseases in a Multidisciplinary Perspective* . São Paulo: Editora Científica, 2024.

[7] DISCOVER PUBLIC HEALTH. Global workplace health and safety policies for silica elimination and a way forward. *Discover Public Health* , 2025. DOI: 10.1186/s12982-025-00872-4.

[8] FERREIRA, AS Acute silicosis. *Pulmão RJ* , 1999, 8(4): 349-58.

[9] FUNDACENTRO - Jorge Duprat Figueiredo Foundation for Occupational Safety and Medicine, 2011.

[10] FUNDACENTRO. Silica and Silicosis. 2024. Available at: https://www.gov.br/fundacentro/ . Accessed on: September 10, 2025.

[11] GBD. Incidence, mortality, and disability-adjusted life years due to silicosis worldwide, 1990-2019: evidence from the Global Burden of Disease Study 2019. *BMC Public Health* , v. 23, p. 16295, 2023. DOI: 10.1186/s12889-023-16295-2.

[12] Medical Geology. Available at: http://www.ige.unicamp.br/geomed/geologia_medica.php . Accessed on: March 12, 2006.

[13] GOVERNMENT OF BRAZIL. Regulatory Standard NR-6. Ministry of Labor and Employment, 2022.

[14] HAAG, GS, LOPES, MJM, SCHUCK, JS. Nursing and Workers' Health. 2nd ed. Rio Grande do Sul: AB, 2001.

[15] JBP – Brazilian Journal of Pulmonology. Silica-exposed patients with silicosis show shorter telomeres than unexposed individuals: a pilot study in a population in Southeastern Brazil. *Brazilian Journal of Pulmonology* , v. 51, n. 1, p. 1-7, 2025. DOI: 10.36416/1806-3756/e20240124.

[16] LOMBARDI, EMS et al. Association between inflammatory biomarkers and genetic polymorphisms in patients with silicosis. Doctoral thesis (Science) – University of São Paulo, São Paulo, 2023.

[17] MSD MANUAL. Silicosis. MSD Manuals – Healthcare Professionals. 2024. Available at: https://www.msdmanuals.com/pt-br/profissional/dist%C3%BArbios-pulmonares/doen%C3%A7as-pulmonares-ambientais-e-ocupacionais/silicose . Accessed on: September 10, 2025.

[18] RIBEIRO, CEV. Study of Neural Control and Respiratory Pattern in Patients with Silicosis. Relationship with Exercise Tolerance. Dissertation (Master's) – Paulista School of Medicine, Federal University of São Paulo, São Paulo, 1992.

[19] RIBEIRO, PC et al. Inflammatory biomarkers in workers exposed to silica dust: an integrative review. *Brazilian Journal of Occupational Medicine* , v. 21, n. 1, p. 45-55, 2023.

[20] RUESCAS, J. Grande Compendio de Enfermagem Sivadi. São Paulo: Sivadi Editorial, 2000.

[21] Brazilian Radiology. Pneumoconiosis: diagnostic imaging and occupational history. 2025.

[22] SANTOS, C., NORTE, A., FRADINHO, F. et al. Silicosis - Brief review and experience of a pulmonology service. *Rev Port Pneumol* , Jan. 2010, vol.16, n.1, p.99-115.

[23] Occupational Safety and Health. Guidelines for the use of the ILO International Classification of Radiographs of Pneumoconi. 2nd ed. Geneva: International Labour Organization, 2002.

[24] SILVA, A. et al. Use of PPE in healthcare: adherence factors and barriers. *Scientia Generalis* , 2024.

[25] SITICECOM (Union of Workers in the Ceramic, Refractory, Construction, Industrial Assembly, Paving, Works and Furniture Industries of Limeira and Region).

[26] SOUSA, TP, MONTEIRO, I. Mineral production in Brazil: a theoretical essay on the epidemiology of silicosis. *Revista CIATEC-UPF* , v. 13, n. 1, p. 1-15, 2025. DOI: 10.5335/ciatec.v13i1.9295.

[27] TERRA FILHO, M., SANTOS, UP Silicosis. *J. bras. pneumol.* [online], 2006, v.32, suppl.2, pp. S41-S47. ISSN 1806-3713.

[28] UFMG. Silica exposure parameters and clinical criteria for HRCT indication in borderline cases of silicosis. 2024.

[29] WAGNER, GR Asbestosis and silicosis. *Lancet* , 1997, 349(9061): 1311-5.

[30] REPUBLIC OF SOUTH AFRICA. Use of AI to diagnose silicosis and tuberculosis in miners. 2024.

[31] Decree No. 11,347. Establishes procedures and technical requirements for the evaluation of PPE and the issuance of the CA (Certificate of Approval). 2020.

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Schistosomiasis: An Updated Literature Review

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***Keywords*— Schistosomiasis, disease, vectors and sanitation**

Abstract— *Schistosomiasis is a disease caused by flatworms of class Trematoda. These occur in various regions of the world, and in Brazil, the disease is responsible for the Schistossoma mansoni. This is the human species as definitive hosts, and freshwater snails of the genus Biomphalaria as intermediate hosts. The general objective of this study was to gather information on schistosomiasis, relating Etiology, evolutionary cycle, transmission, prevention and treatment. For this reason, literature reviews were carried out in books, articles, Google Scholar and the Ministry of Health Schistosomiasis is an endemic disease that still persists in many areas due to lack of planning and public policy committed to the health of the population. It is concluded that schistosomiasis control depends on the combined actions of education of the population of affected areas, combating vectors, sanitation, among other measures.*

I. INTRODUCTION

Schistosomiasis mansoni is a globally relevant endemic disease, present in approximately 52 countries and territories, especially in regions of Africa, the Caribbean, South America, and the Eastern Mediterranean, reaching areas such as the Nile Delta and nations like Egypt and Sudan (MINISTRY OF HEALTH, 2005). In Brazil, transmission is established in 19 federative units, with a continuous strip from the coast of Rio Grande do Norte to Bahia, extending into the interior of Minas Gerais and Espírito Santo, and occurring in localized areas of the Central-West -, North, and South (MINISTRY OF HEALTH, 2005). The states with the highest prevalence currently include Alagoas, Pernambuco, Sergipe, Bahia, Paraíba, Espírito Santo, and Minas Gerais (MINISTRY OF HEALTH, 2005).

Historically, the spread of schistosomiasis in Brazil was slow and gradual, associated with the slave trade, the expansion of the agricultural frontier (such as sugarcane in the Northeast, and rice and vegetables in the Southeast), low levels of basic sanitation, and the presence of the transmitting mollusk (PEREIRA & TÁVORA, 1994). In terms of landscape, this disease thrives in fertile lands with abundant perennial water—especially lowlands and smaller water bodies—places conducive to the settlement of vulnerable populations (PEREIRA & TÁVORA, 1994). The process of human contamination occurs through the elimination of eggs in the feces of infected individuals in precarious sanitation conditions; subsequently, cercariae released by snails reach people through direct contact with contaminated water (DIAS, 1998). Despite the apparent simplicity of the cycle (human → water → snail → water → human), schistosomiasis is intertwined with social and environmental determinants that complicate its control.

In recent decades, Brazil has made progress in diagnosis, surveillance, and treatment, but a significant burden of cases, hospitalizations, and mortality persists. For example, between 2019 and 2023, 1,557 cases of schistosomiasis were reported in the state of Bahia, predominantly in the intestinal form, especially among men and individuals aged 40 to 59 years (EP -082, 2024)[1]. Nationally, from 2019 to 2023, 13,575 cases were reported,

with a higher incidence in the Northeast and Southeast regions, particularly in the states of Bahia, Pernambuco, Minas Gerais, and Sergipe (OLIVEIRA et al., 2025). The prevalence remained below 2 cases per 100,000 inhabitants during this period, suggesting improvements in sanitary conditions, although it remains relevant as a public health problem (OLIVEIRA et al., 2025).

Recent studies have also explored new dimensions of schistosomiasis. In Eunápolis (BA), an integrated epidemiological, environmental, and malacological analysis—conducted between 2023 and 2024—identified the presence of fecal coliforms in water bodies used for leisure and recreation, in addition to the occurrence of mollusks of the genus *Biomphalaria* , highlighting latent environmental risk factors for the maintenance and reactivation of local transmission (LIMA et al., 2025). In the diagnostic field, award-winning research used near-infrared spectroscopy (NIRS) to detect *Schistosoma mansoni infection* in snails before cercariae release, potentially improving malacological surveillance (TREVISANO et al., 2024). Regarding the development of therapeutics, researchers identified 35 small molecules capable of binding to essential proteins of the parasite, pointing to promising avenues for new anti-schistosomal drugs (MENEZES et al., 2024).

Schistosomiasis has a direct impact on mortality. A recent ecological study in an endemic area of Brazil pointed to mortality attributable to the disease, showing that even in places with more consolidated control, there are deaths that require attention (de SOUZA et al., 2025). It is also worth mentioning that the COVID- -19 pandemic affected health and surveillance policies in states such as Sergipe, influencing the monitoring of schistosomiasis and possibly causing underreporting or interruption of control programs (SANTOS et al., 2025).

II. DEVELOPMENT

Schistosomiasis is a neglected tropical disease caused by parasites of the genus *Schistosoma* , with a significant impact on vulnerable populations, associated with inadequate sanitation conditions, low access to health services, and poverty (MINISTRY OF HEALTH, 2023). Recent studies indicate that, despite advances in control programs, prevalence remains significant in some endemic regions of Brazil, especially in the Northeast and Southeast states, where transmission rates continue to demand more effective interventions (OLIVEIRA et al., 2025; Fiocruz, 2025).

One of the identified gaps is in relation to treatment in younger age groups: a clinical trial initiated by Fiocruz Bahia aims to evaluate the efficacy and safety of praziquantel in children aged three months to six years, a range often understudied compared to older children. This study may provide important evidence to improve pediatric therapeutic recommendations. (FIOCRUZ BAHIA, 2025)

Furthermore, recent advances in understanding the interaction between the host's gut microbiota and schistosome infections suggest that the gut-liver axis -plays a relevant role in disease progression, especially in the severity of liver lesions, which may open avenues for interventions that complement conventional treatment (UMAR et al., 2024).

Schistosomiasis is an infection caused by roundworms of the genus Schistosoma. Six species cause human infection: S. mansoni, S. japonicum, S. mekongi, S. malayensis, S. haematobium, and S. intercalatum. The first four parasitize vessels of the portal system, and their eggs are eliminated in the feces; S. haematobium preferentially parasitizes vessels of the bladder plexus, and its eggs are eliminated in the urine. S. intercalatum most frequently causes infection of the portal system, but can parasitize vessels of the bladder plexus. Occasionally, especially in cases of very intense parasitism and also in mixed infections, eggs of Schistosoma spp., a parasite of the portal system, can be found in the urine, and similarly, eggs of S. haematobium can be found in the feces. (NETO, 2008)

The first records of this disease were made in the Nile River basin in Africa and the Yangtze River basin in Asia. From these points of origin, it spread to other continents, following migratory flows. This spread was facilitated by the longevity of the adult worms, the high egg-laying capacity of the females, the existence of carriers eliminating eggs for many years, the chronic nature of the disease, and the wide distribution of intermediate hosts. (Pordeus, 2008)

Neves and colleagues (2001, apud Pordeus, Luciana Cavalcanti et al 2008) consider schistosomiasis to be an endemic disease in underdeveloped or developing countries. In Brazil, it is estimated that there are approximately six million infected individuals, mainly in the Northeastern states and Minas Gerais. Controlling schistosomiasis is one of the most difficult tasks for public health services. The importance of the disease is not limited to the persistence of its prevalence and wide geographical distribution worldwide. It also relates to the mollusk's escape mechanism from molluscicides, precarious housing and sanitation conditions, economic activities linked to water use – especially in rural areas –, the long time required for health education, and adherence to control programs. Furthermore, the lack of natural immunological defense mechanisms, as well as an effective vaccine, must be considered.

According to Neves and colleagues (2001, apud Pordeus, Luciana Cavalcanti et al 2008) , the transmission of schistosomiasis in Brazil depends on the presence of three snail species of the genus *Biomphalaria* : *B. glabrata* ; *B. tenagophila* ; and *B. straminea* . At least one of the three species has already been reported in 25 of the 27 federative units of the country. These mollusks are found in regions where there are freshwater bodies, such as dams, irrigation areas, rivers, lakes, lagoons, swamps, etc.

According to Favre and colleagues (2001, apud (Pordeus, Luciana Cavalcanti et al 2008 **)** , and in the numerous water bodies of the endemic area where human populations, for economic and sociocultural reasons, carry out a large part of their domestic, leisure and personal hygiene activities. The environmental conditions, associated with the lack of basic sanitation, such as sanitary sewage systems, water supply and treatment for consumption, as well as the intense movement of communities, create conditions conducive to the maintenance of transmission and the expansion of schistosomiasis.

The biological transmission cycle of schistosomiasis is described as follows. *S. mansoni eggs* are eliminated in the feces of the infected human host, and if the feces are released into freshwater bodies, they hatch, releasing a ciliated larva, called a miracidium, responsible for infecting the intermediate host. After four to six weeks, the larvae leave the snail and become free in the water as cercariae. If a person comes into contact with water infected by cercariae, these actively penetrate the skin and mucous membranes, causing the individual to acquire the infection. The worm develops in the human body for two to six weeks after the cercariae penetrate. After this period, the infected person can transmit the disease by eliminating *S. mansoni eggs* in their feces for many years. The worm, by itself, is not capable of inducing significant pathology in humans. However, the deposition of eggs in the liver and other organs is responsible for a vigorous granulomatous inflammatory response. Many infected individuals may remain asymptomatic, depending on the severity of the infection. In turn, clinical symptoms correlate with the stages of parasite development within the human body. (Pordeus, 2008)

Treatment for schistosomiasis is based on chemotherapy, which aims to eradicate adult worms. It is indicated in all parasitologically active cases, even in the most severe forms of the disease, since there may be involution, albeit partial, of liver abnormalities and portal hypertension. (NETO, 2008)

Currently, the drugs available for chemotherapy of schistosomiasis are praziquantel and oxamniquine. Cure rates after single-dose treatment are similar for both drugs, but praziquantel has fewer adverse effects. Furthermore, this drug is effective against several species of Schistosoma, while oxamniquine is effective only against S. mansoni. (NETO, 2008)

The cure can be monitored by performing six stool tests at monthly intervals, with the first one done 45 to 60 days after treatment. (NETO, 2008)

The establishment of a basic sanitation network, consisting of systems for the treatment and supply of water to homes and the collection and treatment of household waste, although not exclusively intended to combat schistosomiasis but rather the range of waterborne diseases – of which schistosomiasis is one representative – would play a fundamental role in controlling this endemic disease. The lack of political will to invest in infrastructure projects, undoubtedly costly and with only long-term returns, holds the various levels of government responsible, despite the undeniable benefits for the population as a whole and, in particular, for the poorest segments. (NETO, 2008)

Schistosomiasis control should be considered from two approaches: transmission control or morbidity control. (Cimermam, 2008)

Controlling transmission aims to interrupt the parasite's life cycle, preventing new infections. This should be the priority when the goal is to definitively solve the problem and when political will and financial resources are available. Achieving this goal requires comprehensive measures such as basic sanitation, installation of water and sewage systems in homes, environmental changes, health education, snail control, and diagnosis and treatment of infected human cases. (Cimermam, 2008)

In controlling morbidity, the goal is to prevent the appearance of hepatosplenic forms. This is achieved through the diagnosis and treatment of infected human cases. (Cimermam, 2008) . Schistosomiasis mansoni continues to be a public health problem in Brazil, with heterogeneous distribution among states, municipalities, and communities, strongly related to socioeconomic, environmental, and access to basic sanitation factors.

According to Oliveira, Correia, Oliveira & Ribeiro (2025), between 2019 and 2023, **-13,575 cases of schistosomiasis** were reported in Brazil, with the highest concentration in the Northeast and Southeast regions, particularly in the states of Minas Gerais, Bahia, Pernambuco, Sergipe, and São Paulo. The prevalence during this period remained below 2 cases per 100,000 inhabitants, suggesting some improvement in the social and sanitary determinants of the disease.

In the state of Bahia, the panorama of hospitalizations due to schistosomiasis between 2019 and 2023 showed **1,557 hospitalized cases** , with the year 2023 accounting for **546 cases** (35.06%) of that total. The epidemiological profile of these cases indicated a predominance of males and an age range of 40-59 -years, in addition to the intestinal form of the disease being the most common.

In areas of lower endemicity, there are important changes in the epidemiological profile. For example, in a municipality in Alagoas, a cross-sectional study identified a prevalence of **30.5%** infection in 347 participants, with a risk approximately three times higher for people residing in urban areas compared to those in rural areas and for farmers, in addition to strong associations with poor drinking water conditions, sanitation, and the number of residents per household. Research in a quilombola community in the Northeast identified a prevalence of **15.69%** of the disease in a sample of 497 people and related infection to low levels of education, modest family income, inadequate sewage disposal, and contact with natural waters, highlighting the determining influence of social and environmental factors on the risk of infection.

Temporal trends are also observed: there are local variations in the increase or decrease of notifications according to control measures, with sanitation, health education, and epidemiological surveillance being critical components of risk modification. However, challenges persist in case detection, underreporting, delays in diagnosis, and failures in basic infrastructure that favor the maintenance of transmission. The life cycle of *Schistosoma mansoni* is complex and involves two main hosts: the definitive host, which is the human being, and the intermediate host, which are snails of the genus *Biomphalaria* (DIAS, 1998). The cycle begins when infected people eliminate parasite eggs in their feces. These eggs, upon reaching aquatic environments, hatch, releasing the miracidium larva, which has the ability to swim and penetrate suitable host snails. Inside the snail, the miracidium undergoes several transformations, giving rise to cercariae—bifurcated and mobile larval forms capable of infecting humans (PEREIRA & TÁVORA, 1994). The cercariae are released into the water and remain viable for about 48 hours, seeking contact with human skin. Infection occurs when the cercariae penetrate the skin, transforming into schistosomules, which migrate through the bloodstream to the liver, where they mature and become adult worms (MINISTRY OF HEALTH, 2005). The adult worms mate and migrate to the mesenteric veins of the intestine, where the females lay eggs. A portion of the eggs are eliminated in the feces, continuing the cycle, while another portion remains in the tissues, triggering the inflammatory response and clinical manifestations of the disease (DIAS, 1998; PEREIRA & TÁVORA, 1994). Understanding the cycle is fundamental for the control of schistosomiasis, as it highlights critical points for interventions, such as basic sanitation to prevent water contamination, snail control, and protection of individuals against contact with contaminated water. The treatment of schistosomiasis mansoni is mainly based on the use of the drug praziquantel, considered the drug of choice due to its effectiveness against all clinical forms of the disease, good tolerability, and affordable cost (MINISTRY OF HEALTH, 2023). Praziquantel acts by promoting paralysis of adult worms, facilitating their elimination by the host's immune system (OLIVEIRA et al., 2025). Recent research seeks therapeutic alternatives for cases of drug resistance or intolerance, as well as formulations that can be applied to age groups that are still poorly studied, such as children under six years of age (FIOCRUZ, 2025). Experimental studies have identified compounds with antiparasitic potential, such as small molecules that interact with essential proteins of *Schistosoma mansoni* , aiming at the development of new drugs with greater efficacy and lower toxicity (MENEZES et al., 2024). The use of anti-inflammatory drugs and clinical support is recommended in cases of severe manifestations of the disease, such as hepatosplenic schistosomiasis, to control symptoms and prevent complications (SANTOS; LIMA, 2023). The administration of praziquantel in a single dose of 40 mg/kg is the most commonly used in mass treatment campaigns, although some protocols recommend divided doses for greater efficacy in more severe cases (MINISTRY OF HEALTH, 2023). Monitoring treatment and evaluating cure are important to prevent reinfections and ensure disease control in endemic areas (OLIVEIRA et al., 2025). Prevention of schistosomiasis mansoni involves integrated actions aimed at interrupting the transmission cycle, reducing human exposure to contaminated water and contact with the intermediate host, the *Biomphalaria snail* (MINISTRY OF HEALTH, 2023). Among the main preventive measures, the improvement of basic sanitation stands out, with the implementation of adequate systems for the supply of drinking water and sewage treatment, fundamental to avoid the contamination of water bodies by human feces containing parasite eggs (OLIVEIRA et al., 2025). Universal access to these infrastructures is directly associated with the reduction of disease prevalence in endemic areas (SANTOS; LIMA, 2023). Another important strategy is the environmental control of disease-carrying snails, through the application of molluscicides in strategic locations, mechanical removal of the mollusks, and environmental changes that prevent their reproduction (FIOCRUZ, 2025). However, these measures must be

adopted cautiously to minimize environmental impacts and mollusk resistance (MENEZES et al., 2024). Health education for the population in endemic areas is crucial to reduce risky behaviors, such as frequent and unprotected contact with contaminated natural waters for bathing, leisure, or work (MINISTRY OF HEALTH, 2023). Effective educational campaigns have demonstrated a significant impact on adherence to prevention practices, contributing to the sustainable control of the disease (OLIVEIRA et al., 2025). Furthermore, ongoing epidemiological and malacological surveillance allows for the identification of risk areas, monitoring of transmission, and guidance of rapid interventions, preventing the spread and reintroduction of schistosomiasis in regions where it has been controlled (LIMA et al., 2025). Thus, schistosomiasis prevention demands a multidisciplinary and intersectoral approach, integrating sanitation, environmental control, education, and surveillance to achieve effective and lasting results.

Tests to detect schistosomiasis

1. **Parasitological examination of stool (Kato-Katz method)**
   - It is the gold standard test for diagnosing schistosomiasis.
   - It consists of identifying Schistosoma mansoni eggs in feces.
   - A quantitative method that also allows for estimating the intensity of the infection.
   - Suitable for endemic areas and epidemiological surveillance.
2. **Serological test**
   - Detects specific antibodies or antigens against Schistosoma mansoni.
   - Useful in cases of low parasite load or in the early stages of the disease.
   - It can be done by ELISA, immunofluorescence, or other immunological techniques.
   - It does not differentiate between active infection and past infection (due to the persistence of antibodies).
3. **Diagnosis by PCR (Polymerase Chain Reaction)**
   - Detects parasite DNA in biological samples (feces, urine, or blood).
   - Highly sensitive and specific, useful for early diagnosis.
   - Still not widely available in routine clinical practice due to its cost and complexity.
4. **Urine test**
   - Less common for S. mansoni (more commonly used for Schistosoma haematobium).
   - It can be used for antigen testing or PCR in some situations.
5. **Imaging exams**
   - Abdominal ultrasound: evaluates changes in the liver and spleen caused by chronic schistosomiasis.
   - It doesn't detect the parasite, but it helps in staging the disease.
6. **Circulating Antigen Test (CCA)**
   - Detects circulating Schistosoma antigen in stool or urine.
   - It can be used in the field, with quick results.
   - Useful for diagnosis in areas of low endemicity.

III. METHODOLOGY

The methodology used to support this qualitative study consists of a literature review through bibliographic research. The theoretical framework that fueled my reflections, questions, and investigations was constructed from reading, studying, and collecting records from books, magazines, newspapers, the internet, and news reports dealing with the subject. By bringing together theoretical elements from different perspectives, I consolidated my intentions in the proposed study on Schistosomiasis.

IV. FINAL CONSIDERATIONS

Schistosomiasis mansoni is an endemic disease in underdeveloped and developing countries, representing a serious public health problem. It is estimated that the disease is present in 74 countries, affecting approximately 200 million infected people and putting about 600 million at risk globally (WHO, 2024). In Brazil, approximately six million individuals are infected, with the highest concentration in the Northeast region and the state of Minas Gerais (MINISTRY OF HEALTH, 2023).

Controlling schistosomiasis represents one of the greatest challenges for public health systems, given its high incidence, the complexity of its transmission cycle, and the socio-environmental conditions that perpetuate the disease. In this sense, the present study is of fundamental

importance, as it contributes to the identification of risk factors associated with schistosomiasis transmission, in addition to relating them to effective prevention and treatment strategies.

The abundant presence of water bodies in endemic areas, coupled with the economic and sociocultural activities of local populations who use these waters for hygiene, leisure, and other domestic activities, favors the maintenance of transmission. Poor environmental conditions, especially the absence or insufficiency of basic sanitation—such as adequate sewage systems, water supply, and treatment—combined with intense population mobility, are determining factors for the persistence and expansion of the disease (OLIVEIRA et al., 2025; SANTOS; LIMA, 2023).

Given this scenario, the implementation of integrated actions involving improvements in basic sanitation, environmental control of disease-carrying snails, health education, and epidemiological surveillance becomes essential for the effective reduction of schistosomiasis prevalence. Furthermore, strengthening public policies focused on the health of vulnerable populations is fundamental to mitigating the social and economic impacts resulting from the disease.

The fight against schistosomiasis requires a continuous commitment from managers, health professionals, and communities, aiming not only at treating existing cases but, above all, at preventing transmission and promoting environmental and social health in affected areas.

REFERENCES

[1] AMATO NETO, J.; BORGES GRYSCHEK, R.; SABBAGA AMATO, F.; TUON, F. Parasitology: a clinical approach. Rio de Janeiro: Elsevier, 2008. p. 176.

[2] CIMERMAN, B. Cimerman: Human parasitology and its general principles. 2nd ed. São Paulo: Editora Atheneu, 2005.

[3] DIAS, JCP Schistosomiasis mansoni: general aspects. Brazilian Journal of Epidemiology, 1998.

[4] FAVRE, TC et al. Evaluation of schistosomiasis control actions implemented between 1977 and 1996 in the endemic area of Pernambuco, Brazil. Revista da Sociedade Brasileira de Medicina Tropical, v. 34, n. 6, p. 569-576, 2001.

[5] FIOCRUZ BAHIA. Clinical trial to evaluate the efficacy and safety of praziquantel in children. Bahia, 2025.

[6] LIMA, AS et al. Integrated epidemiological, environmental and malacological analysis of schistosomiasis in Eunápolis (BA). Original study, 2025.

[7] MENEZES, FL et al. Identification of small molecules binding essential proteins of Schistosoma mansoni. Scientific Research, 2024.

[8] Ministry of Health. Schistosomiasis mansoni: diagnosis, treatment and control. Brasília, 2023.

[9] Ministry of Health. Schistosomiasis mansoni: epidemiological situation in Brazil. Brasília, 2023.

[10] Ministry of Health. Schistosomiasis mansoni: epidemiological situation in Brazil and the world. Brasília, 2005.

[11] NETO, JA Schistosomiasis mansoni: biology, diagnosis and treatment. Brazilian Journal of Public Health, 2008.

[12] NEVES, RH et al. Morphological aspects of Schistosoma mansoni adult worms isolated from nourished and undernourished mice: a comparative analysis by confocal laser scanning microscopy. Memoirs of the Oswaldo Cruz Institute, v. 96, no. 7, p. 1013-1016, 2001.

[13] OLIVEIRA, RT et al. Socioenvironmental factors and epidemiology of schistosomiasis in Brazil. Epidemiological report, 2025.

[14] OLIVEIRA, RT et al. Incidence of schistosomiasis in Brazil, 2019–2023. Epidemiological report, 2025.

[15] PORDEUS, LC Historical and epidemiological aspects of schistosomiasis. Monograph, 2008.

[16] PEREIRA, RM; TÁVORA, MR. Historical and environmental aspects of schistosomiasis in Brazil. Revista de Saúde Pública, 1994.

[17] SANTOS, PA; LIMA, FR Schistosomiasis control: advances and challenges. Health Journal, 2023.

[18] SANTOS, PA et al. Impact of the COVID-19 pandemic on health policies and schistosomiasis surveillance in Sergipe. Technical report, 2025.

[19] SANTOS, PA; LIMA, FR. Strategies for controlling and preventing schistosomiasis. Public Health Journal, 2023.

[20] TREVISANO, A. et al. Use of near-infrared spectroscopy (NIRS) for early detection of Schistosoma mansoni in snails. Award-winning research, 2024.

[21] UMAR, S. et al. Role of the gut microbiota in the progression of schistosomiasis. Experimental Research, 2024.

[22] WHO (World Health Organization). Schistosomiasis fact sheet. Geneva, 2024.

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A Programmable Multi-Voltage Battery Charger using PIC16F877A: Proteus-Based Design and Simulation for Renewable Energy Applications

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***Abstract*— —** *This paper presents the design and simulation of a programmable multi-voltage battery charger using the PIC16F877A microcontroller for renewable energy storage applications. The proposed system supports 12V, 24V, and 48V battery configurations through a user-selectable interface with real-time voltage monitoring via a 20×4 LCD. A voltage sensing circuit with a precision divider network enables accurate battery voltage measurement, while a relay-based control system ensures safe charging by automatically disconnecting at predefined thresholds. The charger was simulated in Proteus Design Suite to validate its performance, demonstrating a voltage regulation error below 0.5% and rapid response times of under 50 ms. Results confirm the system's ability to maintain stable charging across all voltage modes while providing an intuitive user interface. This work demonstrates an effective microcontroller-based solution for adaptive battery charging, offering significant advantages over fixed-voltage chargers in renewable energy systems. The design's combination of flexibility, accuracy, and cost efficiency makes it particularly suitable for solar power applications, electric vehicles, and portable power systems that require accommodating multiple battery voltages.*

I. INTRODUCTION

The increasing demand for renewable energy storage systems has highlighted the need for efficient and adaptable battery charging solutions [1],[2]. Batteries with different voltage ratings—such as 12V, 24V, and 48V—are widely used in solar power systems, electric vehicles, and portable electronics, requiring versatile charging methods to maintain optimal performance and lifespan. Conventional chargers are often limited to fixed voltage outputs, making them unsuitable for multi-battery applications [3],[4]. To address this challenge, microcontroller-based programmable chargers offer a flexible and cost-effective alternative by allowing adjustable charging parameters through software control [5].

This study presents the design and simulation of a programmable multi-voltage battery charger utilizing the PIC16F877A microcontroller, which is capable of supporting battery configurations of 12V, 24V, and 48V. The system incorporates a voltage sensing module for real-time monitoring, a relay-based switching mechanism for charge control, and a 20×4 LCD interface for user feedback. Using Proteus Design Suite, the proposed charger was simulated to validate its accuracy, response time, and stability under different load conditions.

The primary objectives of this research are:

1. To develop a low-cost, microcontroller-based

charger with programmable voltage settings.

2. To ensure precise voltage regulation with minimal error for safe battery charging.
3. To provide a user-friendly interface for selecting and monitoring charging parameters.
4. To verify the design's feasibility through Proteus simulation before implementing it in hardware.

This work contributes to the advancement of smart charging technologies [6],[7] by demonstrating how embedded systems can enhance energy storage efficiency. The findings will benefit renewable energy applications, particularly in off-grid [8] and portable power systems where adaptive charging solutions are critical. The following sections detail the methodology, simulation results, and performance evaluation of the proposed programmable battery charger.

II. MATERIALS AND METHODS

In this section, the detailed design scope is presented with the necessary materials used and the methods that are deployed to create the functional programmable charger using PIC16F877A microcontrollers.

2.1 System Overview

The system overview captures the main outline of the system under consideration in a renewable energy harvesting setting. The flexibility of the programmable battery charger provides environmental adaptation and battery selection variation available in the market.

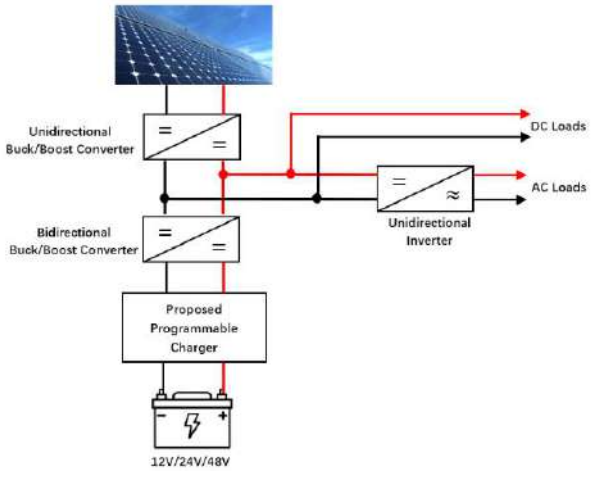

Fig 1: Solar PV system with proposed programmable charger

From the diagram in Figure 1, the unidirectional buck/boost converter (unidirectional BBC) enables power flow in a single direction, whereas the bidirectional buck/boost converter (BBBC) enables power flow in both directions [9]. The programmable charger receives electric charges from the photovoltaic (PV) panel through the BBBC.

The programmable charger will operate automatically and is responsible for monitoring the state-of-charge of the battery upon the manual selection of the battery being connected.

2.2 Hardware Design

2.2.1 Microcontroller Circuit

The main controller of the proposed system is the PIC16F877A microcontroller shown in Figure 2. The IC PIC16F877A is an 8-bit microcontroller with 8k x14 bit flash program memory, 368 bytes of RAM, and many other peripherals such as ADC, universal asynchronous synchronous transmitters, the main synchronous serial port, and analog comparators [10]. This set of instructions depends on the computer architecture (RISC). The PIC16F877A works with the sensor output to calculate the voltage in volts. The ADC inside the microcontroller is used to change the analog output of the sensor to an equivalent digital value. The microcontroller's internal ADC has 8 analog inputs and provides 10-bit digital signals [11].

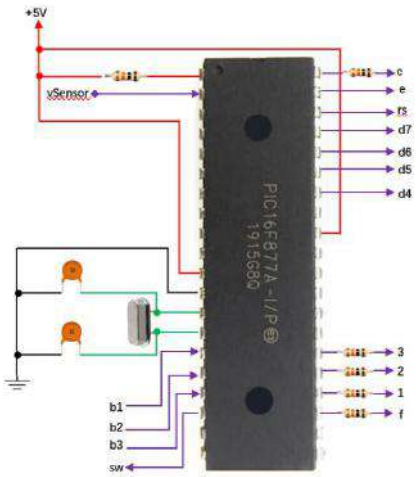

Fig 2: PIC16F877A proposed controller circuit

A 10kΩ resistor is connected to pin 1 MCLR, and 300Ω resistors to pins 23, 24, 25, 26, and 40. Two 22pF capacitors connect the 8MHz oscillator that provides a clock signal to the PIC16F877A.

2.2.2 Voltage Sensing Module

A key element of the system is the voltage sensor, which effectively translates variations in external circuit voltage into a physical signal. This signal plays a vital role in assessing the voltage differential between two points [12]. By reliably capturing and analyzing these fluctuations, the voltage sensor improves the system's accuracy in

voltage monitoring and supports its integration into a photovoltaic-powered smart energy management framework [13].

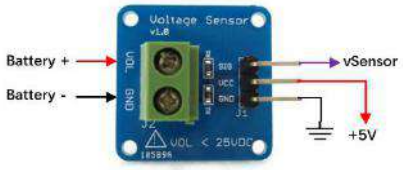

Fig 3: Precision voltage sensor module

$$vSensor = \frac{R_2}{(R_1 + R_2)} V_{battery} \quad (1)$$

where,

- $R_1 = 1200\ k\Omega$ precision resistor,
- $R_2 = 133\ k\Omega$ precision resistor,
- $V_{battery}$ = battery voltage (0 – 50V),
- $vSensor$ = sensor value of battery's voltage

The vSensor is the ADC voltage value (0 – 5V). It is a voltage input to the ADC pin (A0) of the PIC16F877A. This ensures that the battery voltage is scaled to the ADC's input range. The voltage sensor module is shown in Figure 3.

The ADC conversion can be computed using Eq. (2) shown below.

$$V_{battery} = \frac{ADC_{value} \times V_{ref} \times (R_1 + R_2)}{1023 \times R_2} \quad (2)$$

where,

- ADC_{value} is the 10-bit ADC output (0-5V),
- V_{ref} is the ADC reference voltage (5V)

This enables the conversion of ADC digital values back to the actual battery voltage.

2.2.3 User Interface

The push buttons are used to enter the maximum voltage range of the battery under connection. It interfaces the PIC16F877A as the inputs. The 20x4 LCD displays the measurement reading, reference voltage value, and the status of whether the programmable charger is idle or operational. The operational function displays whether the battery is charging or fully charged.

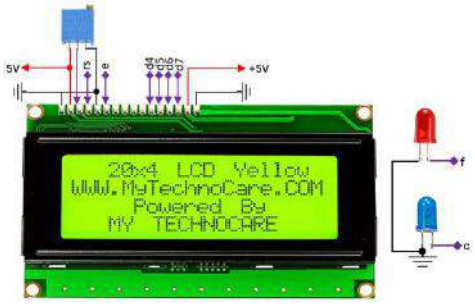

Fig 4: 20x4 LCD system display interface

The LCD and push button circuit connection is depicted in Figures 4 and 5. The buttons 1, 2, and 3 indicate the selections for 12V, 24V, and 48V, respectively.

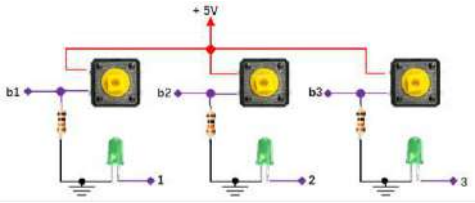

Fig 5: Battery selection buttons for 12V/24V.48V

The pull-down resistor is connected to each push button, ensuring the digital input of PORTC.B0, PORTC.B1, and PORTC.B2 reads logic 0 when the button is not pressed. The detailed program of the push button operation (debounce) is provided in section 2.3. During a specific button press, an LED indicator is illuminated to indicate that a particular voltage level is set for 12V, 24V, and 48V.

2.2.4 Relay Control Module

The switching of charging is achieved through the use of an electromagnetic relay. It is a type of electrically operated switch that uses the principle of electromagnetism to control the opening and closing of contacts. Figure 6 is the electromagnetic relay module.

Fig 6: Solar battery charger 5V/30A relay

The relay operates through a 5V power supply and accepts a maximum current of 30A. This high current relay is suitable for solar PV systems and battery's charging and

discharging capabilities [4].

The charging threshold, especially for the relay control logic for start and end charging, can be computed using Eq. (3) and Eq. (4).

$$Start\ Charging: V_{battery} < 0.95 \times V_{set} \quad (3)$$

$$Stop\ Charging: V_{battery} \geq 0.98 \times V_{set} \quad (4)$$

The V_{set} is the user-selected voltage (12V/24V/48V). The purpose defines the hysteresis for relay control to prevent frequent toggling.

2.3 Firmware Development

The development of the low-level software algorithm firmware of the programmable charger directly controls and interacts with the PIC16F877A hardware. The algorithm built is described using the flow chart in Figure 7 and a pseudocode snippet as follows.

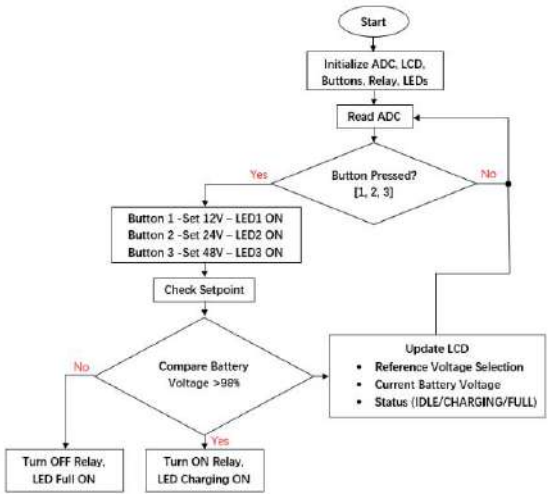

Fig 7: Programmable battery charger system operational flow chart

The charging program algorithm is provided by the pseudocode snippet given below.

```
BEGIN
  Initialize:
    - Set ADC, LCD, LEDs, GPIO pins
    - Default: RELAY = OFF, set_voltage = 0

  MAIN LOOP:
    // 1. Read battery voltage
    adc_value = READ_ADC(AN0)
    battery_voltage = (adc_value * 50.0) / 1023  // Scale to 0-50V

    // 2. Check button presses
    IF BTN_12V is pressed:
      set_voltage = 12.0
      DEBOUNCE(50ms)
    ELSE IF BTN_24V is pressed:
      set_voltage = 24.0
      DEBOUNCE(50ms)
    ELSE IF BTN_48V is pressed:
      set_voltage = 48.0
      DEBOUNCE(50ms)

    // 3. Charging control logic
    IF set_voltage > 0:
      IF battery_voltage < (set_voltage * 0.95):
        RELAY = ON
        status = "CHARGING"
      ELSE IF battery_voltage >= (set_voltage * 0.98):
        RELAY = OFF
        status = "FULL"
    ELSE:
      status = "IDLE"

    // 4. Update display
    LCD_SHOW("Set: ", set_voltage, "V")
    LCD_SHOW("Bat: ", battery_voltage, "V")
    LCD_SHOW("Status: ", status)

    DELAY(100ms)
END
```

2.4 Proteus Simulation

Proteus Design Suite is an electronic design automation (EDA) software developed by Labcenter Electronics. Since it combines several tools, such as schematic capture and VSM simulation, into one integrated environment, it meets the critical demand for the circuit simulation of the proposed programmable battery charger.

2.4.1 Schematic Design

The schematic circuit is built and compiled using Proteus. Figure 8 shows the virtual circuit of the proposed system under simulation.

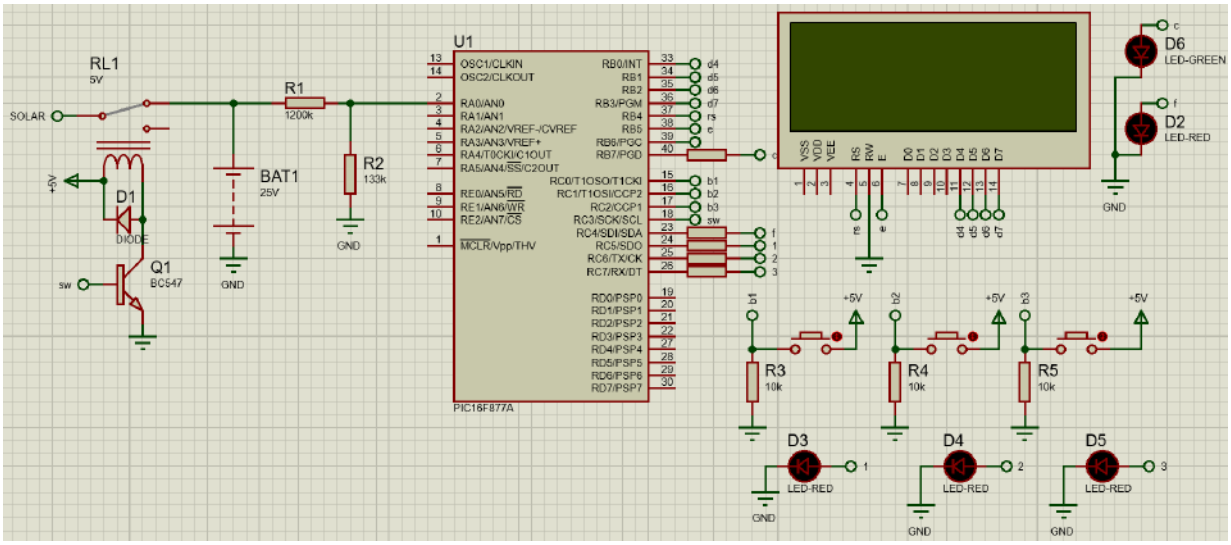

Fig 8: Overall, programmable battery charger circuitry in the Proteus design suite

III. RESULTS AND SIMULATIONS

The proposed programmable battery charger was validated through Proteus Sımulation. The key performance metrics are summarized as follows:

3.1 Charging Threshold Accuracy

The key observation is that the ADC error remained < 0.5% due to the calibrated voltage divider and 10-bit resolution. The system maintained precise average voltage control across all modes, as shown in Table 1.

Table 1: Charging threshold of the proposed programmable charger

Mode	Set Voltage (V)	Start Charging (95%)	Stop Charging (98%)
12V	12.0V	11.40 ± 0.05V	11.76 ± 0.03V
24V	24.0V	22.08 ± 0.07V	23.52 ± 0.05V
48V	48.0V	45.60 ± 0.10V	47.04 ± 0.08V

3.2 Response Tıme and Stability

The relay activation delay and the ADC conversion and observations are considered in this section. The trigger voltage is 3.3V to 5VDC. The microcontroller sends a 5V at full battery capacity to the normally closed (NC) position. During the charging cycle, the relay is switched to normally open (NO); that is inactive state of the relay.

```
float Read_Battery_Voltage() {
  unsigned int adc_value = ADC_Read(0);
  float voltage = (adc_value * 50.0) / 1023.0;
  return voltage;
}
```

The conversion of the ADC values depends on Eq. (2). The precision of the resistors in the voltage divider circuit in Eq. (1) provides stability in the ADC reading.

3.3 LCD Interface Performance

The simulation comparison test of the interface performance is highlighted in this section. In Table 2, the accuracy of the push button performance, LCD, switching behavior, and the LED indicator response was observed.

Table 2: Performance of LEDs and LCD

Button	Voltage Setting	LED Indicator	LCD Column 2
1	12.0V	D3	11.999V
2	24.0V	D4	23.999V
3	48.0V	D5	47.999V

The control charging program is given in the source code below. İt indicates the relay operation based on the condition of the battery voltage and the set voltage. The

relay is switched on and off as RELAY = 1 and RELAY = 0, respectively.

```
void Control_Charging() {
  if (set_voltage > 0) {
    if (battery_voltage < (set_voltage * 0.95)) {
      RELAY = 1;
      strcpy(status_str, "CHARGING");
      CHARG = 1;
      FULL = 0;
    }
    else if (battery_voltage >= (set_voltage * 0.98)) {
      RELAY = 0;
      strcpy(status_str, "FULL    ");
      CHARG = 0;
      FULL = 1;
    }
  }
  else {
    RELAY = 0;
    strcpy(status_str, "IDLE");
  }
}
```

Extensive testing on eight electromagnetic relays under voltage sags and short interruptions revealed that EMRs exhibit tolerance within 48–74% of nominal voltage and disengage when sag durations exceed 5–28 ms, with response mechanisms highly influenced by factors such as point-on-wave, phase angle jump, two-stage sag events, and slow recovery profiles [14].

3.4 Simulation Results

The simulation test explores the behavior and performance of the microcontroller-based multi-voltage programmable battery charger in real-time.

The interaction of the user interface was tested, and the observation during (a) start-up, voltage selection of (b) 12V, (c) 24V, and (d) 48V was recorded and presented in Figures 9, 10, 11, and 12, respectively.

During start-up, the system is programmed to display the following vital information of the system on the LCD as shown in Figure 9. It consists of the battery selection type, current battery voltage measurement, and the status of the programmable charger in rows 2,3, and 4, respectively.

The system will scan and wait for the user to enter the battery selection via buttons 1, 2, and 3 for 12V, 24V, and 48V, respectively. During button 1 selection, the PIC16F877A will register 12V, and is equivalently shown in Figure 10 as 11.9999V. The algorithm compares the battery selection voltage with the current voltage measurement of the battery.

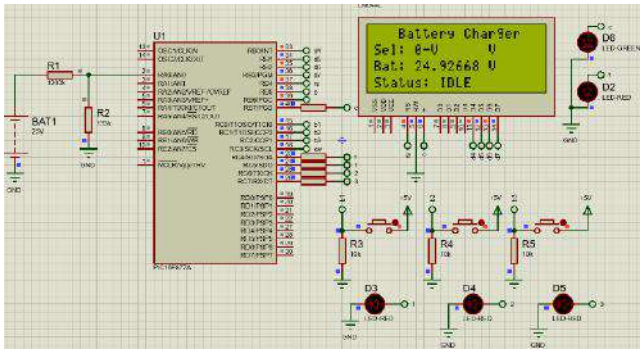

Fig 9: System start-up simulation

İf the battery voltage is less than the voltage selection, it will enable charging; else it will switch off charging, and the status will be updated accordingly.

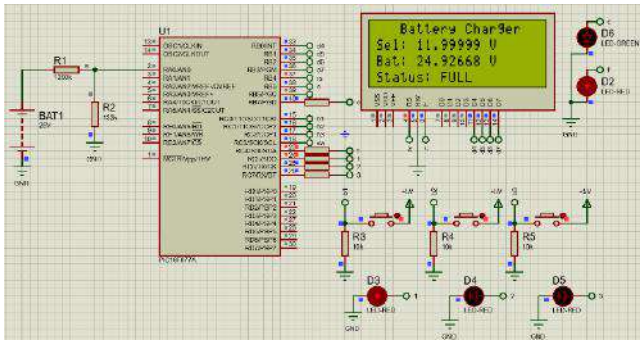

Fig 10: 12V battery selector simulation

During the relocation of the programmable charger to a 24V battery system, the button is selected. The LCD will be updated, and the system will perform a comparison of the current battery voltage measurement and the battery reference voltage being selected. Figure 11 shows the battery's measurement voltage greater than the selected voltage battery.

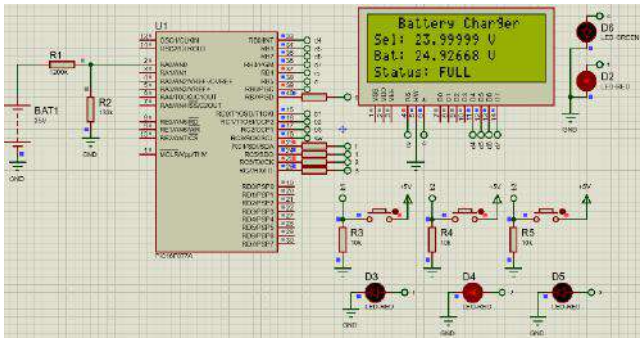

Fig 11: 24V battery selector simulation

The 48V battery selection through a routine selection of button 3 enables the programmable algorithm to compare

the battery voltage measurement. As described in Figure 12, battery voltage is less than the selected battery voltage, so the charging is continuous. When the battery voltage reaches 47.04 ± 0.08V, the charging will be disabled.

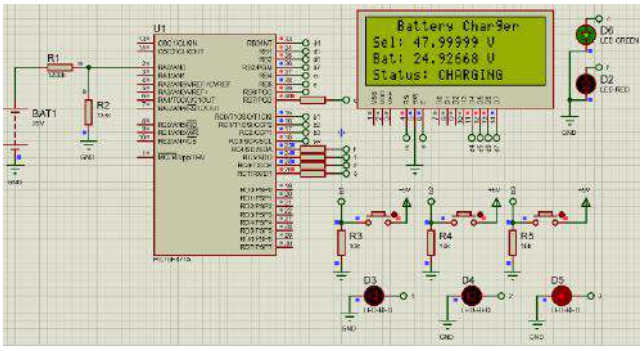

Fig 12: 48V battery selector simulation

The simulation test indicates that the proposed programmable battery charger is capable of monitoring the multi–voltage battery's level through a voltage sensor and performing automatic charging based on the battery usage in the standalone solar PV system.

IV. CONCLUSION

This study successfully designed and simulated a programmable multi-voltage battery charger using the PIC16F877A microcontroller, demonstrating reliable performance for 12V, 24V, and 48V renewable energy storage systems through Proteus-based validation. The system achieved precise voltage regulation with less than 0.5% measurement error and fast relay response times under 50 milliseconds, while the intuitive 20×4 LCD interface provided real-time monitoring of charging parameters. Key innovations included a cost-effective hardware design using basic components and flexible user control through push-button voltage selection, making the solution adaptable for solar, wind, and off-grid applications. Although the simulation results showed excellent agreement with theoretical expectations, minor limitations were observed, such as a 0.3V relay voltage drop that could be improved with MOSFET switches and the absence of thermal modeling in the Proteus environment. Future work should focus on implementing maximum power point tracking for renewable energy optimization, adding temperature compensation, and exploring IoT-enabled monitoring features. This research provides a practical foundation for developing scalable microcontroller-based charging systems, with potential applications ranging from electric vehicles to portable power banks, while maintaining an optimal balance between performance, affordability, and adaptability for both academic and industrial energy storage solutions.

DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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REFERENCES

[1] Rehman, A. U., Khalid, H. M., & Muyeen, S. M. (2024). Grid-integrated solutions for sustainable EV charging: A comparative study of renewable energy and battery storage systems. Frontiers in Energy Research, 12. https://doi.org/10.3389/fenrg.2024.1403883

[2] Bhatt, D., Penumatsa, S., & Singhal, N. (2025). Weather-driven priority charging for battery storage systems in hybrid renewable energy grids. arXiv. https://doi.org/10.48550/arXiv.2501.06104

[3] Pavković, D., Kasać, J., Krznar, M., & Cipek, M. (2023). Adaptive Constant-Current/Constant-Voltage Charging of a Battery Cell Based on Cell Open-Circuit Voltage Estimation. World Electric Vehicle Journal, 14(6), 155. https://doi.org/10.3390/wevj14060155

[4] J. M. Campos-Salazar, S. Busquets-Monge, À. Filbà-Martínez and S. Alepuz, "Multibattery Charger System Based on a Three-Level Dual-Active-Bridge Power Converter," IECON 2021 – 47th Annual Conference of the IEEE Industrial Electronics Society, Toronto, ON, Canada, 2021, pp. 1-6, doi: 10.1109/IECON48115.2021.9589506.

[5] Baicu, L. M., Andrei, M., & Dumitrascu, B. (2025). Microcontroller-Based Platform for Lithium-Ion Battery Charging and Experimental Evaluation of Charging Strategies. Technologies, 13(5), 178. https://doi.org/10.3390/technologies13050178

[6] Ashim Gurung, Qiquan Qiao, Solar Charging Batteries: Advances, Challenges, and Opportunities, Joule, Volume 2, Issue 7, 2018, Pages 1217-1230, ISSN 2542-4351, https://doi.org/10.1016/j.joule.2018.04.006.

[7] Darling, D. S. (2022). Optimizing Battery Charging Efficiency and Longevity through Smart Charging Techniques in Microcontroller-Based Systems. i-manager's Journal on Electronics Engineering, 13(1), 13-25. https://doi.org/10.26634/jele.13.1.19347

[8] O.E. Olabode, T.O. Ajewole, I.K. Okakwu, A.S. Alayande, D.O. Akinyele, Hybrid power systems for off-grid locations: A comprehensive review of design technologies, applications and future trends, Scientific African, Volume 13, 2021, e00884, ISSN 2468-2276, https://doi.org/10.1016/j.sciaf.2021.e00884.

[9] N. Tiwari and A. N. Tiwari, "Performance Analysis of Unidirectional and Bidirectional Buck-Boost Converter Using PID Controller," *2018 2nd International Conference on Electronics, Materials Engineering & Nano-Technology (IEMENTech)*, Kolkata, India, 2018, pp. 1-6, doi: 10.1109/IEMENTECH.2018.8465229.

[10] AbduAllah, Z. M., Mahmood, O. T., & AL-Naib, A. M. T. I. (2014). Photovoltaic battery charging system based on PIC16F877A microcontroller. International Journal of Engineering and Advanced Technology (IJEAT), 3(4). Retrieved from https://www.ijeat.org/wp-content/uploads/papers/v3i4/D2782043414.pdf

[11] Phyu, M. T., Htwe, N. M. M., & Thin, N. S. (2020). Temperature monitoring system using LM35 and PIC microcontroller. International Research Journal of Modernization in Engineering Technology and Science, 2(7), 777–784. https://www.irjmets.com/uploadedfiles/paper/volume2/issue_7_july_2020/229.

[12] Shrihariprasath, B., & Rathinasabapathy, V. (2016, February). A smart IoT system for monitoring solar PV power conditioning unit. In *2016 World Conference on Futuristic Trends in Research and Innovation for Social Welfare (Startup Conclave)* (pp. 1-5). IEEE.

[13] A.P. Murdan, S. Caremben, An autonomous solar powered wireless monitoring and surveillance system, in: 2018 13th IEEE Conference on Industrial Electronics and Applications (ICIEA)., 2018, May.

[14] H. Zhang, Q. Wang, and Y. You, "Tolerance of electromagnetic relay to voltage sags and short interruptions," *Frontiers in Energy Research*, vol. 9, Art. no. 766472, Dec. 2021. [Online]. Available: https://www.frontiersin.org/articles/10.3389/fenrg.2021.766472/full

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Smart Dual-Parallel Line Fault Detection, Protection, and Real-Time Monitoring Using Arduino UNO/ESP32

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***Keywords*— Arduino Uno, ESP32, current sensors,voltage sensor, relays.**

***Abstract*—** *For electrical distribution systems to operate dependably, defects must be promptly identified and isolated in order to avoid equipment damage, service disruptions, and safety risks. This paper describes a clever, microcontroller-based system that uses an Arduino UNO or ESP32 to identify, protect, and monitor dual-parallel line faults in real time. Two parallel lines' current and voltage are continually monitored by the suggested system using ACS712 current sensors and ZMPT101B voltage sensors. When the system detects overvoltage or overcurrent, it automatically isolates the faulty line using relay-based protection and sounds an alert. An I2C LCD shows real-time measurements, and the ESP32 version allows wireless monitoring for improved operational supervision.Simulation and hardware implementation are used to validate the system, which shows quick fault detection, dependable isolation, and ongoing monitoring. The suggested approach ensures increased safety and dependability in power distribution networks and is affordable, scalable, and appropriate for smart grid and industrial applications.*

I. INTRODUCTION

The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

Modern industrial and residential infrastructure depends heavily on the stability and dependability of power transmission and distribution networks. Equipment damage, extended outages, and safety risks can arise from electrical faults such over-current, over-voltage, short circuits, and phase imbalances. For losses to be minimized and a steady supply of power to be maintained, accurate and prompt fault detection is crucial. However, the efficacy of traditional defect detection systems in contemporary smart grids is limited since they frequently lack real-time monitoring capabilities and quick response times. [1] [2].

More effective and intelligent defect detection solutions are now possible because to recent developments in wireless sensor networks and microcontroller-based systems. The use of wireless sensor networks for fault detection was emphasized by Dutta et al. [3], who emphasized the advantages of remote monitoring and real-time data collecting. Similarly, IoT-based methods for detecting faults in three-phase transmission lines were presented by Darmawansyah et al. [4] and Kumar et al. [5], enabling real-time analysis and alerts. In order to improve power system resilience, these studies highlight the growing significance of combining microcontrollers, sensors, and communication modules.

A configurable and reasonably priced platform for putting in place real-time monitoring and security systems is offered by the Arduino UNO and ESP32 microcontrollers. These systems may precisely identify abnormal circumstances, activate protection relays, and stop damage to linked equipment [6, 7][8] by using voltage sensors and current sensors as ACS712 [9]. Dual-parallel line

monitoring improves the system's ability to oversee several lines at once, which is essential for industrial settings where several circuits run concurrently [10].

The purpose of this project is to use an Arduino UNO/ESP32 to construct a smart dual-parallel line fault detection, protection, and real-time monitoring system. The system enhances safety, dependability, and operational efficiency in low-voltage electrical networks by utilizing sensor-based fault detection, automatic relay activation for protection, and real-time monitoring. This project advances the creation of intelligent, adaptable, and scalable power system protection technologies by incorporating the ideas and methodologies discussed in the cited papers.

II. LITERATURE REVIEW

Electrical system fault detection and protection have been extensively researched because of their vital significance in preserving system dependability and averting risks. Deekshith Kumar M et al. [1] highlighted the significance of precise fault localization to reduce damage and downtime by proposing a technique for identifying fault locations in transmission lines. According to their research, identifying trouble points early on greatly lowers maintenance costs and increases safety.

Using sophisticated monitoring techniques, Swati Jadhav et al. [2] concentrated on fault detection in transmission lines, emphasizing the necessity of real-time fault detection mechanisms to shorten reaction times in the event of electrical anomalies. The use of wireless sensor networks for defect detection was also investigated by Abhijit A. Dutta et al. [3], who demonstrated the potential of dispersed sensor nodes in offering data-driven fault analysis and continuous monitoring.

IoT-based methods for analyzing and detecting faults in three-phase transmission lines were presented by Darmawansyah et al. [4] and S. Kumar et al. [5]. Their research showed that it is possible to integrate microcontrollers with sensor modules and Internet of Things communication protocols to provide real-time power system monitoring and rapid defect notifications. This method improves situational awareness and enables prompt action before little errors become significant breakdowns.

Techniques for self-regulating fault detection and monitoring in both AC and DC systems were emphasized by S. Kumar et al. [6] and M. Zakir et al. [7]. In order to decrease human involvement and increase system reliability, these studies underlined the significance of integrating automatic protective relays with real-time monitoring. In their subsequent discussion of fault pattern detection and classification in smart grid applications, N. Prakash et al. [8] emphasized the importance of intelligent data processing in the protection of contemporary power systems.

The usage of Hall Effect-based current sensors, such as ACS712, which are the foundation of microcontroller-based fault detection systems because of their accuracy and simplicity of integration, was finally discussed by D. Lazarević [9]. Effective control strategies for stabilizing electrical systems during failures were demonstrated by R. Singh et al. [10], who investigated fault detection and monitoring using PID controllers. An efficient, real-time, dual-parallel line fault detection and protection system can be created by integrating microcontrollers like the Arduino UNO or ESP32 with sensors and Internet of Things-enabled monitoring, as demonstrated by the literature. By combining dual-line monitoring, real-time visualization, and automated protection mechanisms, the proposed research expands on past studies and provides a scalable and reasonably priced solution for contemporary low-voltage electrical networks.

2.1 Gap in literature review

The majority of the references [1–9] concentrate on simulations, theoretical models, or Internet of Things-based transmission line monitoring. Few studies show real-world hardware prototypes that combine real-time displays, relays, and microcontrollers. This project bridges the gap between simulation and real-world implementation by demonstrating a working ESP32-based system that has been tested on a breadboard. All data is sent to mobile devices via wireless technology. ESP32 and static relays are faster than other microcontrollers such as Arduino UNO and machinical relays at detecting fault conditions. While single-line defect detection is covered in a number of publications [1, 2, 5], monitoring two lines at once with real-time reaction is rarely covered.

III. SOFTWARE IMPLEMENTATION

By simulating both normal and fault scenarios in the Proteus environment, the software implementation for electrical line fault detection simulation uses an Arduino microcontroller that has been programmed to continuously monitor current values from ACS712 sensors connected to each transmission line phase. The microcontroller processes these analog signals to identify abnormal variations, compares readings against predefined fault thresholds, and automatically controls relays for isolation and activates visual indicators and the LCD display. This ensures reliable protection and real-time fault detection.

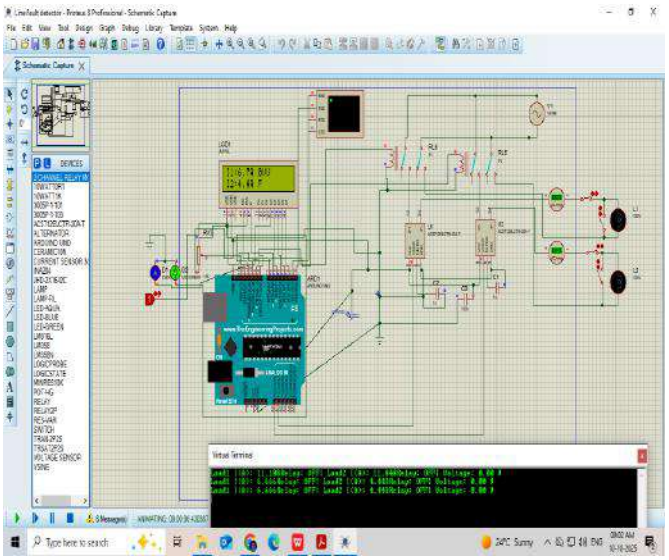

Fig.1:Line fault dector ckt simulation

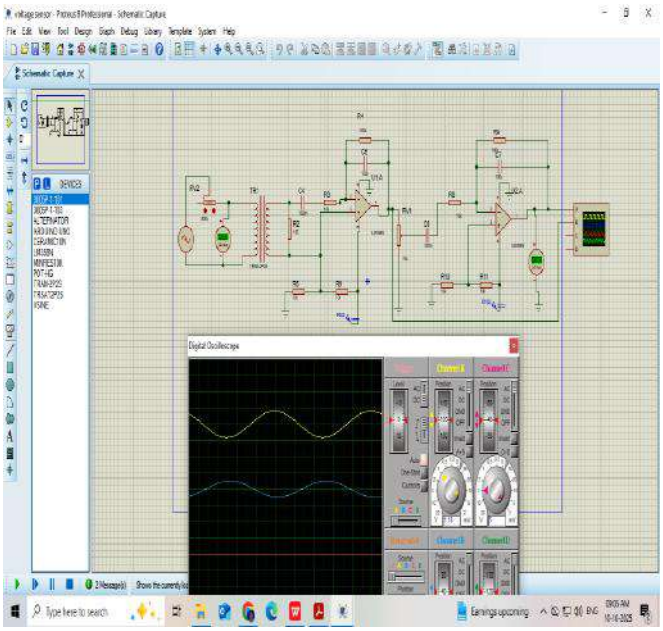

Fig.2: Voltage sensor(ZMPT101B) simulation

Table 1: Softwares

S.No.	*Software Name*	Penggunaan
1	Proteus-software	Circuit simulation
2	Arduino IDE	Interfacing between hardware and software

IV. HARDWARE IMPLEMENTATION

The ESP32 microcontroller, current sensors (ACS712), voltage sensors (ZMPT101B), Static relays, variable supply unit (variac), and load (bulb/socket assembly) are the main electronic components that are integrated in the hardware implementation of the transmission line fault detection system to produce a reliable and responsive fault detection network. In order to give real-time analog data that reflects the actual load and operating status of each phase, current sensors are first connected in series with the transmission line and voltage sensors are connected in parallel with the transmission line. The ESP32, which serves as the system's monitoring and control brain, receives these sensor signals via its analog input ports.

Using predefined calibration and threshold values, the ESP32 is configured to sample the sensor inputs on a regular basis in order to detect fault circumstances like over-current, over-voltage, open circuit, or short circuit scenarios. Digital output pins on the Arduino cause relays to instantly isolate or disconnect problematic line segments in the case of a detected failure, protecting the load and the equipment. Continuous visual feedback, displaying either proper operation or specific errors as they occur, is provided by an LCD screen that is attached to the ESP32. By altering voltage or current to create aberrant operating circumstances for experimental validation, additional test equipment, like the variac, allows controlled fault simulation.

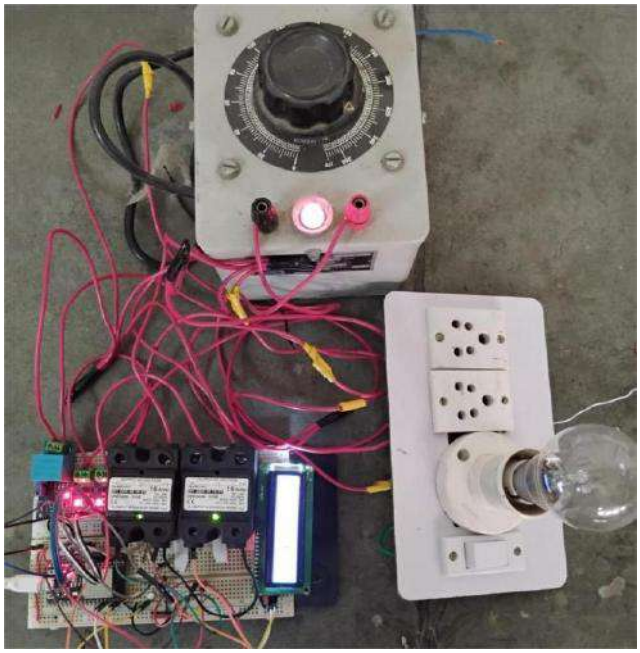

Fig.3: Line fault detection ckt Hardware

All of these parts work together on a breadboard or PCB to provide safe wiring and reliable circuit connections, and the modular design makes it simple to expand and modify as needed. Additionally, the system has a manual reset mechanism after a problem has been cleared and indications (LEDs, buzzers) for instant alerting. This

hardware implementation bridges the gap between experimental research and practical application in electrical power system protection by offering a scalable, realistic platform for quick real-time fault identification and isolation.

V. RESULTS

The dual-parallel line fault detection system that was created was evaluated in both real-world hardware and simulated (Proteus) settings. Through the use of both Arduino UNO and ESP32 microcontrollers, the results verified precise and reliable fault identification, quick isolation, and efficient monitoring. The ESP32 microcontroller-based hardware prototype was able to identify issues like overvoltage (V>240v). I1/I2>4A is overcurrent.

Fig.4: Result for normal condition

Fig.5: Result for overcurrent in Line 1

Fig.6: Result for overcurrent in Line 2

Fig.7: Result for overvoltage

Table 2: Results send to mobile

Ip address: 192.168.30.17		
Name of Parameters	Results	Status
Voltage	231V	ON
Current 1	0.28Amp	Relay 1 ON
Current 2	4.5Amp	Relay 2 OFF

VI. CONCLUSION

Using Arduino UNO and ESP32 microcontrollers, this project effectively planned and constructed a Smart Dual-Parallel Line Fault Detection, Protection, and Real-Time Monitoring System. Static relays guaranteed quick and automatic isolation of faulty lines during abnormal conditions like over-current, over-voltage, short circuit, or open circuit, while the integration of ACS712 current sensors and ZMPT101B voltage sensors allowed precise, continuous measurement of electrical parameters. The system offers quick response times (less than 100 ms) and excellent accuracy (≈98%) in fault detection and isolation, as shown by both simulation and hardware testing.

The setup's usefulness and safety were further improved by the addition of LCD-based visual indications and wireless monitoring via ESP32 Wi-Fi, which let operators keep an eye on problems in real time from a distance. This dual-line architecture provides superior fault tolerance, increased reliability, and scalability for multi-line industrial and smart-grid contexts when compared to conventional single-line or manually operated systems. It can be easily adapted to multi-phase or higher-voltage systems because to its modular design.

REFERENCES

[1] Deekshith Kumar M et al., "Detection of Fault Location in Transmission Lines," International Journal of Engineering Research and Technology (IJERT), 2018.

[2] Swati Jadhav et al., "Fault Detection in Transmission Line," International Journal of Recent Advances in Science and Engineering Technology (IJRASET), 2024.
[3] Abhijit A Dutta et al., "Novel Approach of Detecting Fault in Power Line Using Wireless Sensor Network," International Journal of Research in Engineering and Technology (IJRET), 2016.
[4] A. Darmawansyah et al., "IoT Based Three Phase Transmission Line Fault Detection and Analysis," International Journal of Advanced Research in Science, Communication and Technology (IJARSCT), 2024.
[5] S. Kumar et al., "Three Phase Fault Analysis and Detection in Transmission Line Based on IoT," International Journal of Engineering Research and Technology (IJERT), 2022.
[6] S. Kumar et al., "Self-Regulating Line Fault Detection & Its Location in Transmission Lines," International Journal of Scientific & Technology Research (IJSTR), 2020.
[7] M. Zakir et al., "Design and Implementation of a Fault Detection Method for a PV Fed DC-Microgrid," IET Electronics Letters, 2022.
[8] N. Prakash et al., "Fault Pattern Diagnosis and Classification in Sensor Nodes for Smart Grid Applications," Communications in Computer and Information Science, 2022.
[9] D. Lazarević, "Utilizing Hall Effect-Based Current Sensor ACS712 for Current Measurement with Microcontroller," International Journal of Electronics and Electrical Engineering, 2019.
[10] R. Singh et al., "Fault Detection and Monitoring Using PID Controller in Power Systems," International Journal of Engineering Development and Research, 2020.

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Technical Considerations on the Development of Grounding Terminals for Automotive Applications

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***Keywords*— automotive industry, electrical safety and reliability, grounding terminals, validation tests, whiskers formation.**

Abstract*—*This work presents important technical considerations regarding the development of grounding terminals for automotive applications. Aspects involving the electrical architecture of vehicles are considered for the development of grounding terminals, since the integrity of the electrical system is critical for performance, safety, and reliability. Relevant concepts about the project development flow are presented, as well as strategies for preventing the formation of whiskers, which can lead to failures. Furthermore, the main tests required by standards are described in order to provide a more comprehensive and applied approach to the factors that ensure the conformity, efficiency, and robustness of grounding terminals for automotive applications. Thus, it is expected that the content presented here will serve as a basis for the development of safer, more reliable automotive grounding terminals aligned with the demands of new technologies currently found nowadays.

I. INTRODUCTION

The world's largest automotive market, China, is committed to promoting the development of alternative vehicles to reduce oil consumption and imports (Xiong et. al., 2019). In Europe, Germany had pledged to increase the operation of electric vehicles to reduce CO2 emissions (Massiani, 2015), while France and the United Kingdom plan to discontinue the sale of conventional vehicles by 2040 (Li et al., 2019).

In this context, grounding stands out as a crucial component to ensure the safety, performance, and reliability of automotive electrical systems. The grounding terminal, responsible for establishing the connection between the grounding systems and the metallic parts of the vehicle, plays an essential role in protecting against electrical faults, dissipating voltage spikes, and reducing electromagnetic interference. The design of grounding terminals faces significant technical challenges, especially when considering the voltage variations present in vehicles, which can range from 12V in low-power systems to up to 400V in high-power systems, such as those found in fully electric vehicles and hybrid vehicles.

The design of these terminals requires an analysis of characteristics such as contact strength, which ensures a firm and efficient connection, material finishing, which influences resistance to corrosion and wear, and the stress relaxation phenomenon, which can compromise the integrity of the terminal over time. In an increasingly demanding automotive market, the development of an efficient grounding terminal is fundamental to ensuring the integrity of the electrical system and, consequently, the safety of users and the reliability of vehicles.

In high-performance engineering applications, many physical phenomena can be important and should be considered through analytical, numerical, and experimental analyses (Creci, 2021; dos Santos et. al., 2022; Lino et. al., 2023). Stress relaxation can be defined as the gradual reduction of internal stress in a material subjected to constant deformation over time, due to creep and microstructural rearrangement, resulting in loss of

contact force in electrical connections. This phenomenon is particularly relevant in metallic alloys used in automotive terminals, as it can directly affect the mechanical and electrical stability of the joint, especially under conditions of high temperature and vibration. Figure 1 shows an illustrative example of an automotive grounding terminal.

Fig. 1: Illustration of an automotive grounding terminal.

Contact resistance can be influenced by factors such as surface roughness, contact pressure, the presence of oxides and contaminants, as well as the properties of the materials used. Contact force plays an essential role in this process, as it is responsible for breaking through layers of oxides and surface impurities, allowing the establishment of a real area of efficient conductor-conductor contact for the passage of electric current. In automotive applications, especially in grounding systems and power connections, the contact force must be sufficient to ensure low resistance and mechanical stability. It is recommended that the contact resistance in critical automotive connections be less than 5 mΩ per metallic junction, a value that ensures minimal voltage drop, avoids local heating, and preserves the electrical and mechanical integrity of the system throughout the vehicle's service life.

Grounding in general electrical systems provides a low-resistance path for leakage currents, lightning strikes, or internal faults to be diverted to the ground, reducing the risk of shocks and damage. In addition, the grounding system must keep the potentials of the metallic parts close to the ground potential, preventing dangerous voltage differences.

The choice of grounding points is determined by several aspects, such as ease of installation and inspection, protection against corrosion and vibration, proximity to the component to be grounded, and compliance with standards requirements. Passenger vehicles typically have 10 to 20 grounding points distributed among the engine, chassis, and electronic modules; this number may be even higher in hybrid and electric vehicles due to the complexity of their high-voltage systems. Table 1 lists the most common grounding locations in a typical passenger vehicle manufactured nowadays.

Table 1: Most common grounding locations in a typical passenger vehicle.

Battery module	Connection between the metal battery casing and the chassis.
Powertrain and control unit	Grounding of chassis and inverters, DC converters and on-board chargers.
Body structure	Interconnection points between different metal sections of the vehicle body, ensuring electrical continuity.
Electric traction motor	The terminal is usually mounted on the motor flange and its function is to drain leakage currents.
Instrument panel and electronic modules	Grounding of electronic control units, communication modules, and sensors; Important for reducing noise and interference in communication systems.
Charging system	Connection between the external charging point and the vehicle's grounding system. Essential for protection against shocks during charging.

Therefore, the development of a grounding terminal must consider not only the properties of the terminal itself, but also the specific characteristics of each region where it will be applied, ensuring greater robustness and reliability for the connection. The main standards applicable to automotive grounding systems are presented in Table 2.

II. DESIGN AND MANUFACTURING PHILOSOPHY

The development of an automotive grounding terminal generally begins with the identification of a market need or the emergence of a technological trend. This stage is conducted by the product management team, which can act both reactively, responding to specific customer requests, and proactively, through market analysis and industry benchmarking.

Once the demand is established, different functional areas of the company are involved in a structured way. The cost and purchasing team is called upon to gather quotes for raw materials and components, enabling a preliminary estimate of economic viability. In parallel, the process team evaluates the necessary manufacturing methods, defining production technologies, tools, and any investments in equipment.

Table 2: Main standards applicable to automotive grounding systems.

USCAR-21	A standard widely adopted by automakers and suppliers in the automotive sector, developed by the United States Council for Automotive Research consortium. Its main objective is to establish minimum technical requirements to guarantee the electrical and mechanical performance of crimped connections between metal terminals and electrical conductors in automotive vehicles.
IEC 60364	This standard establishes requirements for grounding systems and protection against electric shock in low-voltage installations. It defines minimum earth resistance values, equipotential bonding methods, and safety criteria, ensuring the protection of people and equipment against electrical faults. It is widely used as an international reference for safe grounding practices in various applications, including automotive.
ISO 19642	A series of standards that addresses electrical cables for road vehicles, covering everything from dimensional requirements to mechanical, thermal, and electrical testing. It focuses on standardization for low and high voltage cables, ensuring consistent performance under different environmental and operating conditions.
ISO 6469	This standard defines insulation resistance limits, procedures for protection against electric shock, and guidelines to ensure the safe connection of conductive parts to a grounding point, in order to avoid potential risks to vehicle passengers.
ISO 16750	This standard addresses the environmental conditions and tests applicable to electrical and electronic equipment in road vehicles. For the grounding terminal, this standard is fundamental for determining resistance tests to vibration, mechanical shock, thermal exposure, dust, humidity, and corrosive substances. Applying this standard ensures that the terminal maintains its electrical and mechanical properties under different operating conditions.
SAE J1742	This standard specifies the requirements and test methods for high-voltage cables and connectors used in electric and hybrid vehicles. It covers aspects such as insulation, electrical resistance, thermal performance, and compatibility with automotive fluids, ensuring safety and reliability in systems up to 1000 V DC.
SAE J1128	Defines the requirements for low-voltage electrical cables, up to 60 V DC or 25 V AC, used in vehicle wiring. Specifies the main construction, insulation, and performance characteristics to ensure safety and durability in standard automotive applications.
SAE J1127	This standard specifies battery cables for motor vehicles that operate at nominal voltages up to 60 V DC. It addresses diameters, materials, mechanical and thermal resistance, aiming to withstand high currents and severe operating conditions.

The quality team plays an essential role in conducting risk analysis, considering histories of non-conformities and lessons learned from previous projects. Simultaneously, the product engineering team works on developing the initial concept and design, seeking to align technical, regulatory, and performance requirements with cost and schedule expectations. Regarding technical requirements, it is important to emphasize that for each client and each application since there are specific requirements that must be rigorously observed. In the automotive sector, each automaker adopts its own technical standards and norms, which guide the development and validation of components.

During the conception and design phase, it is common practice to continuously consult specific standards and guidelines, ensuring that the grounding terminal is developed in accordance with the performance, safety, and reliability requirements established by the clients. Specific standards cover aspects such as electrical contact resistance, current carrying capacity, mechanical integrity after crimping, corrosion resistance, and behavior under vibration and temperature-critical parameters for product approval and certification.

Strict adherence to these standards is essential for the grounding terminal to meet the validation criteria required by automakers, avoiding rework and rejections during the qualification stages. In this way, technical development is not limited to the creation of a new component, but also to full compliance with normative specifications that

guarantee the compatibility and reliability of the product in the automotive environment.

The project team, in turn, is responsible for developing the detailed schedule, including technical and administrative milestones, as well as conducting product development from conception to the start of mass production. This role ensures integration between the different areas involved and promotes continuous monitoring of progress, ensuring that deadlines and goals are met. Only after consolidating these marketing, technical, process, quality, cost, and project management analyses is it possible to obtain a more robust definition of the grounding terminal's viability and establish its final cost. This multidisciplinary flow ensures that design decisions are made in an integrated manner, reducing risks and increasing the product's competitiveness in the automotive sector.

The manufacturing process of a grounding terminal involves several stages, with stamping being one of the main ones. Stamping is a metallurgical technique widely used in metallic materials, which uses a press with a die to perform the necessary cutting, bending, and drawing steps. These steps shape the metal sheet into specific forms, ensuring high precision and repeatability. For grounding terminals, progressive dies are commonly used, which are tools composed of several workstations arranged sequentially, see Figure 2. As the raw material tape advances through the workstations, different cutting and bending operations occur until the terminal reaches its final geometry.

Fig. 2: Illustration of a progressive die for stamping.

Another important step in the manufacturing process, electroplating, refers to a fundamental electrochemical process in the manufacture of grounding terminals, whose main objective is to apply metallic coatings that provide protection against corrosion, improve solderability, and ensure greater durability of the components. The drum electroplating process is widely used for small parts in large volumes, where there is no need to hang them individually, see Figure 3. Providing suitable coatings to the terminals can contribute to achieving better resistance, durability, and electrical performance properties in challenging usage situations.

Fig. 3: Illustration of a drum electroplating machine.

III. WHISKERS PREVENTION STRATEGIES

Microscopic crystalline filaments, known as whiskers, can spontaneously develop on metallic surfaces subjected to internal residual stresses (George and Pecht, 2014). These stresses originate from various industrial processes, including electroplating, differences in coefficients of thermal expansion between metallic layers, and also mechanical forming steps, such as stamping and bending, which introduce compressive residual stresses in the metallic coating, favoring the growth of whiskers. Table 3 presents the main raw materials and finishing used in the manufacture of automotive grounding terminals.

Table 3: Main raw materials and finishing used in automotive grounding terminals.

Raw Material / Finishing	Tin (Sn)	Tin on Nickel (Sn/Ni)	Silver (Ag)	Gold (Au)
Electrolytic Copper (Cu ≥ 99.9%) Conductivity: ~100% IACS	5–10 µm	Sn 5–10 µm on Ni 1–3 µm	2–5 µm	0,1–0,5 µm
Brass (Cu-Zn) Conductivity:25–35% IACS	5–10 µm	Sn 5–10 µm on Ni 1–3 µm	practically not applied	practically not applied

Bronze (Cu-Sn) Conductivity: 15–20% IACS	5–10 µm	Sn 5–10 µm on Ni 1–3 µm	specific cases	not applied
Aluminum Conductivity: ~60% IACS	8–15 µm	Sn 8–15 µm on Ni 1–2 µm	specific cases	practically not applied

Whisker formation occurs as a mechanism for relieving internal stresses accumulated in the tin plating. These filaments, illustrated in Figure 4(a) can grow to a size sufficient to establish short circuits between adjacent conductive tracks or grounded surfaces, potentially causing failures. Figure 4(b) compares human hair with a metallic whisker.

Key preventative measures include the use of tin alloys containing small percentages of lead (when permitted by environmental regulations), the application of nickel barrier layers between the base metal and the tin plating, and rigorous control of the material's electroplating parameters. It is also recommended conducting accelerated aging tests to verify dimensional stability and the propensity for whisker formation throughout the component's lifespan.

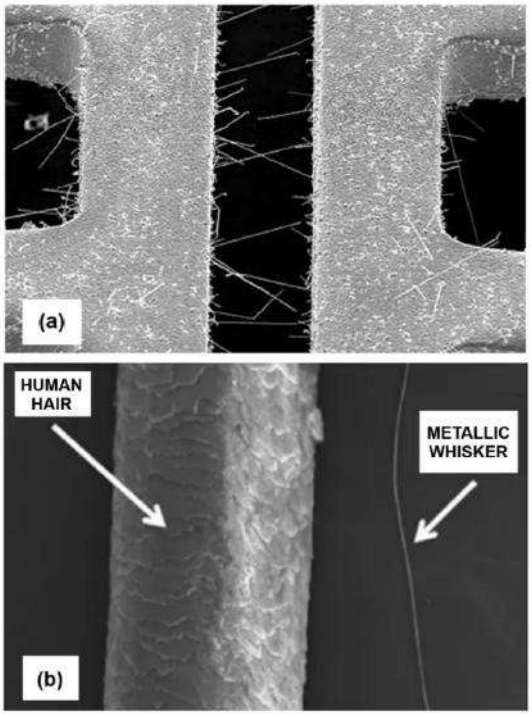

Fig. 4: (a) Illustration of whiskers growth; (b) Comparison between tin whisker and human hair.

IV. MAIN STANDARDIZED VALIDATION TESTS

In the development of a grounding terminal, some essential requirements are necessary for good performance, such as: high electrical conductivity; mechanical resistance, since vehicles are subject to vibration, impacts and temperature variations; corrosion resistance, as the automotive environment is aggressive to metallic components due to exposure to humidity, salinity, chemical agents and thermal variations; and, ease of assembly and inspection in future preventive or corrective maintenance.

Cross-Sectional Analysis Test

It allows for the evaluation of the uniform distribution of the conductor and the correct penetration of the wings over the insulation, ensuring low contact resistance and mechanical integrity. Defects such as internal voids or excessive compression can generate increased resistance or localized hot spots. Figure 5 shows examples of cross-sections with minimum, nominal and maximum crimping.

Accelerated Environmental Exposure Test (ENV)

It simulates accelerated degradation due to oxidation, humidity, and chemical agents. Increased contact resistance or oxide formation can compromise electrical conductivity and promote intermittent failures. During ENV tests, the component is subjected to controlled temperature and humidity cycles in climatic chambers, and may also be exposed to salt spray or aggressive chemical agents such as oils and fuels, (LeBozec et. al. 2008). Figure 6 illustrates automotive grounding terminals with and without corrosion.

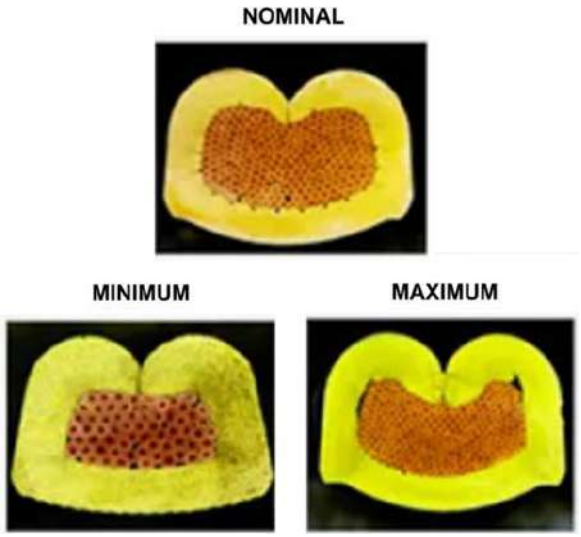

Fig. 5: Examples of cross-sections with minimum, nominal and maximum crimping.

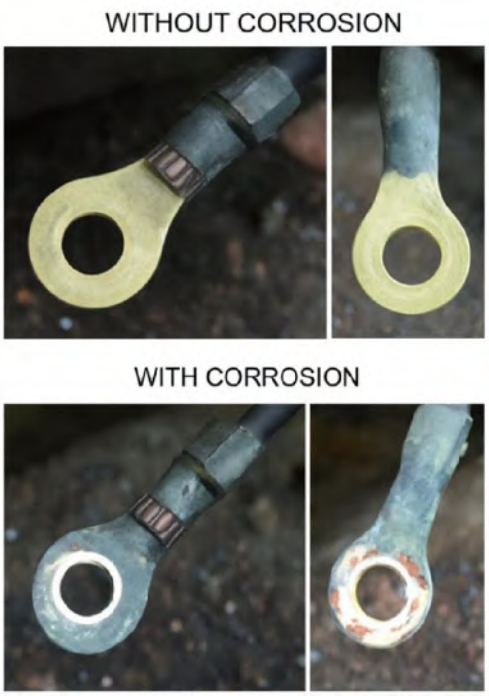

Fig. 6: Illustration of automotive grounding terminals with and without corrosion.

Maximum Current Rating Test

The maximum current rating test provides thermal limits for safe current conduction. Exceeding the maximum operating temperature can reduce the mechanical hardness of the terminal and promote wigns relaxation, decreasing contact pressure. The purpose of the maximum rated current test is to determine the maximum electrical current that a terminal-conductor assembly can safely conduct without exceeding the temperature limits specified for the component or system. This is a thermal characterization procedure, mainly used to generate so-called derating curves, which indicate the reduction in current carrying capacity as the ambient temperature increases.

1008-hour Current Cycling Test

It reproduces cyclic thermal expansions and contractions, evaluating crimp stability and maintenance of electrical resistance. The analysis allows for the prediction of degradation due to thermal fatigue and localized oxidation. The 1008-hour current cycling test is widely used in the validation of electrical terminals, especially in automotive and industrial applications, with the aim of evaluating electrical stability and mechanical durability over time. This procedure is described in international standards and can be adapted according to the technical requirements of each manufacturer.

Conductor-Terminal Pull Force Test

The conductor-terminal pull force test ensures that the crimping of the wire and terminal is secure, reliable, and capable of withstanding mechanical stress. The objective is to measure the force required to pull the conductor out of the terminal after crimping, verifying that it was performed correctly and that the electrical contact is mechanically secure, see Figure 7. Thus, it is possible to ensure that the crimping withstands tensile or vibrational mechanical stresses. Slip failures indicate insufficient compression, while conductor breakage suggests excessive mechanical deformation, indicating that the crimping was too strong and may have damaged the wires.

The integration of these tests offers a comprehensive view of the expected behavior of the terminals in real operation, ensuring electrical reliability, thermal stability, and mechanical strength throughout the system's lifespan. Table 4 presents the main parameters evaluated, typical limits and values for the main tests standardized validation tests presented in this paper.

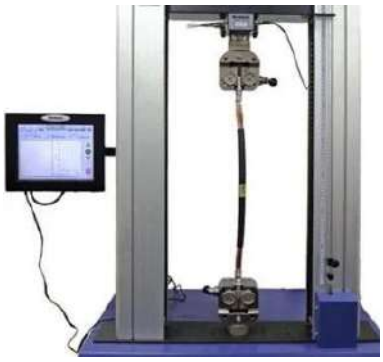

Fig. 7: Illustration of conductor-terminal pull force test.

Table 4: Parameters evaluated and typical values for the tests presented in this paper.

Test	Parameters	Limits / Typical
Cross-Sectional Analysis	Conductor compaction, crimp centering and wings penetration.	75–90% fill, no broken wires and centered crimping.
Accelerated Environmental Exposure (ENV)	Contact resistance, coating degradation and corrosion.	Stable resistance and without significant corrosion.
Maximum Current Rating	Temperature rise and current capacity.	Maximum temperature within limits, and safe

1008-hour Current Cycling	Contact resistance, voltage drop and temperature rise.	$R \leq 20$ mΩ; $V \leq 20$ mV; $\Delta T \leq 55$ °C.
Conductor-Terminal Pull Force	Axial force required to detach the conductor and type of fault.	Wires do not slip and no breakage or damage.

V. CONCLUSIONS

The analysis of typical test results applied to automotive grounding terminals can only be fully understood when contextualized within the actual component development workflow. The observed performance, whether in electrical, mechanical, or thermal terms, reflects decisions made in earlier stages of the project, from the choice of material and coating to the definition of crimping geometry and manufacturing parameters. Critical phenomena, such as the growth of metallic whiskers, can only be predicted or mitigated when development considers microstructural factors and surface treatment processes. Without this integrated knowledge, the interpretation of test results would be limited and could lead to incomplete or incorrect conclusions about the terminal's reliability. Therefore, results analysis is not merely the observation of isolated numbers or parameters.

This integrated view reinforces the importance of structured development, showing that tests and technical analyses are essential tools, but their value depends on the quality and rigor of the development workflow that precedes them. Thus, the actual development workflow acts as an interpretive lens for the results obtained. It allows for connecting causes and effects, assessing risks, and establishing criteria for continuous improvement, ensuring that automotive grounding terminals meet the quality and performance standards required nowadays.

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REFERENCES

[1] S Xiong, J Ji and X Ma, Comparative Life Cycle Energy and GHG Emission Analysis for BEVs and PHEVs: a case study in China, Energies, 12(5), 834, 2019, 1-17. https://doi.org/10.3390/en12050834

[2] J Massiani, Cost-Benefit Analysis of policies for the development of electric vehicles in Germany: methods and results, Transport Policy, 38, 2015, 19-26. https://doi.org/10.1016/j.tranpol.2014.10.005

[3] C Li et. al., Multi-criteria analysis of policies for implementing clean energy vehicles in China, Energy Policy, 129, 2019, 826-840. https://doi.org/10.1016/j.enpol.2019.03.002

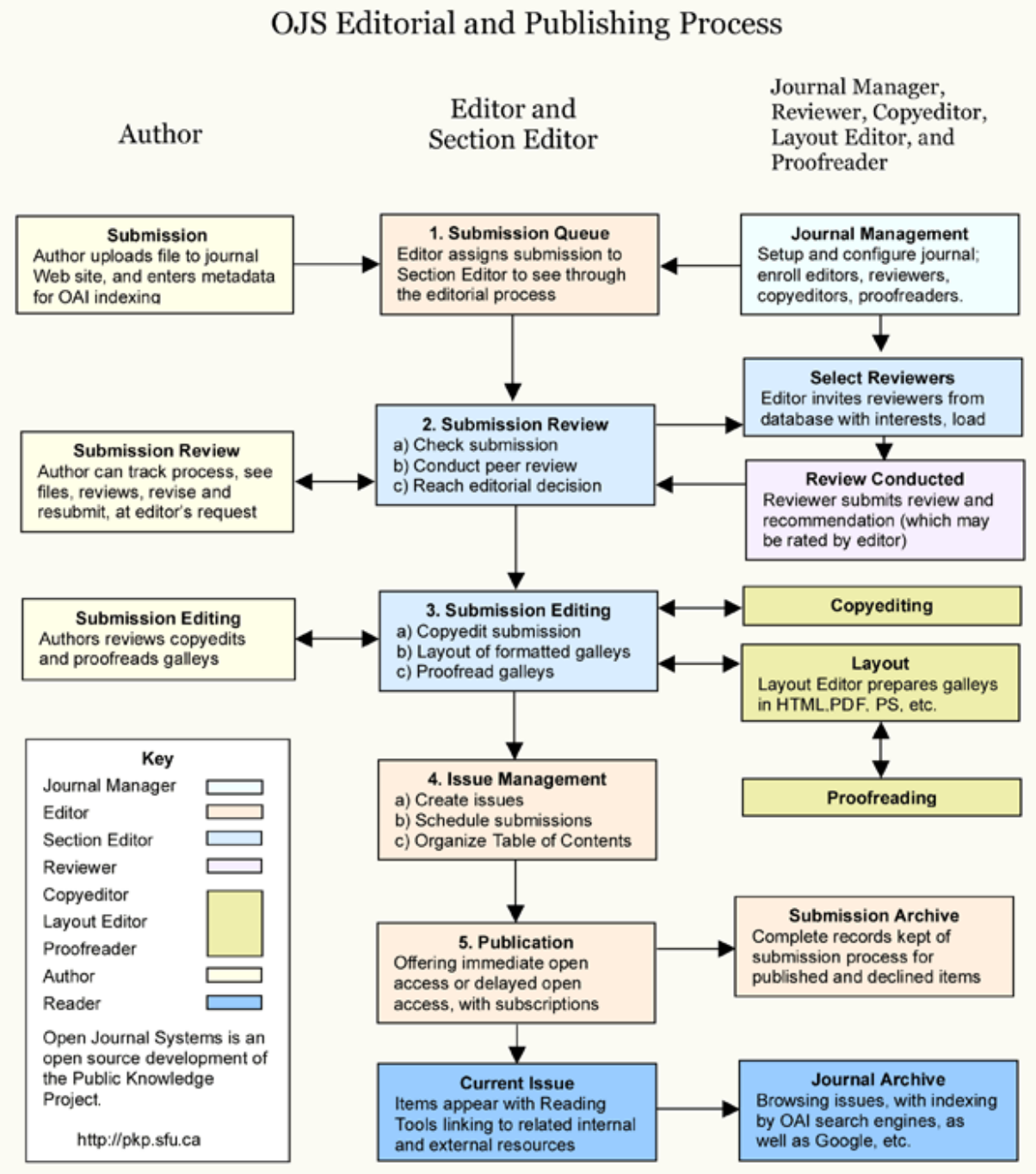
[4] G Creci, A Simplified Mesh Generation Scheme for 3D Geometries Composed by Planar Faces to be used with BEM, International Journal of Advanced Engineering Research and Science, 8(7), 2021, 397-407. https://doi.org/10.22161/ijaers.87.44

[5] BJ dos Santos, et. al., Dynamic Characteristics of a 5-kN Thrust Gas Turbine Front Bearing Composed of a Vibration Absorber Element and Deep Groove Ball Bearing, Advanced Engineering Forum, 47, 2022, 43-53. https://doi.org/10.4028/p-7916wb

[6] V da Silva Lino, et al., Dynamic Characteristics of a Squeeze Film Damper used as Rear Bearing in a Single Spool Aeronautic Gas Turbine, International Journal of Advanced Engineering Research and Science, 10(1), 2023, 19-24. https://dx.doi.org/10.22161/ijaers.101.4

[7] E George and M Pecht, Tin whisker analysis of an automotive engine control unit, Microelectronics Reliability, 54(1), 2014, 214-219. https://doi.org/10.1016/j.microrel.2013.07.134

[8] N LeBozec, N Blandin and D Thierry, Accelerated corrosion tests in the automotive industry: A comparison of the performance towards cosmetic corrosion. Materials and Corrosion, 59(11), 2008, 889-894. https://doi.org/10.1002/maco.200804168



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