

The Undocumented Traditional Use of Apple Vinegar in Two Largest Apple-Growing Moroccan Territories

Driss Ousaaïd^{1,*}, Meryem Bakour^{1,2}, Hassan Laaroussi¹, Asmae El Ghouizi¹, Badiâa Lyoussi¹, Ilham El Arabi¹

¹ Laboratory of Natural Substances, Pharmacology, Environment, Modeling, Health and Quality of Life (SNAMOPEQ). Faculty of Sciences Dhar El Mahraz. University Sidi Mohamed Ben Abdellah, Fez 30000, Morocco

² The Higher Institute of Nursing Professions and Health Techniques (ISPITS), Fez, 30000, Morocco

* Correspondance: driss.ousaaïd@usmba.ac.ma (D.O.);

Scopus Author ID 57214758193

Received: 12.10.2022; Accepted: 24.11.2022; Published: 25.02.2023

Abstract: Traditional medicine is a solid background for many experimental in vivo and in vitro studies. Apple vinegar is an acidic solution with multifaceted purposes experimentally proved. This work was to document different traditional uses of apple vinegar in the two largest apple-growing Moroccan territories, accounting Deraa-Tafilalet and Fez-Meknes. The survey was performed using a semi-structured questionnaire. In total, 200 interviews were conducted to prepare the present survey. The treatment of the obtained results showed that 68% of all respondents use apple vinegar in their medical care, while 32% do not use apple vinegar. Digestive system disorders are the most ailments treated with apple vinegar (42%), followed by skin diseases with a percentage of 33%. While cardiovascular, genitourinary, neuropsychic, and respiratory disorders represent 8%, 6%, 6%, and 5%, respectively. Among users, 79% declare that the utilization of apple vinegar improves patient state, while 14% confirm the appearance of side effects and 7% show signs of intoxication. According to the interviewed people, apple vinegar exhibited numerous pharmacological properties which need more systematic exploration in animal models.

Keywords: apple vinegar; traditional medicine; pharmacological properties; survey; ethnopharmacological study.

© 2023 by the authors. This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The interaction of humans with their environment continues, and the exploration of its resources is still ongoing. It is very difficult to ascertain the right time for the first traditional medicinal plant use, a common practice in rural communities. According to the World Organisation Health, approximately 80% of the world's population still uses medicinal plants as the first health care of their affections [1]. Apple vinegar has been used in different civilizations for multiple purposes as a natural agent with tremendous properties [2,3]. The Egyptians were probably the first to use apple vinegar [3]. It is used for many culinary purposes and appears as an ingredient in 150 recipes in *De Re Coquinaria* [2]. As documented by Caesar's *De Bello Gallico*, vinegar is diluted in water as a refreshing, healthy drink for Roman soldiers and common citizens [2]. This culture has been developed over time and has recently gained the scientific community's attention to understand its biological properties scientifically. Several researchers have selected apple vinegar as a promising product candidate to counteract several health disorders [4–11].

The ethnopharmacological studies provide a solid background of different uses of medicinal plants, which have been practiced for thousands of years worldwide [12]. Despite their various characteristics and may have certain defects, these natural products are still a considerable repository of pharmacological knowledge [13,14]. In fact, apple vinegar is used as a natural agent to prevent the deleterious effects of chemical agents, including hydrogen peroxide, D-glucose, nicotine, hypercaloric diet, and tetramethylpyrazine [5,15–17].

Apple vinegar has a unique phytochemical diversity which induces different biological properties and drug-like activities. Until now, there is no report documenting the traditional use of apple vinegar. This investigation is a pioneering study in Moroccan documenting the traditional knowledge of apple vinegar as a natural product with multi-effects scientifically proved in our previous reports. To our knowledge, this is the first report conducted to explore different traditional uses of apple vinegar in the two largest Moroccan apple-growing regions, Draa -Tafilalet and Fez-Meknes.

2. Materials and Methods

2.1. Study area.

Draa -Tafilalet region is located in the South-East of Morocco; it borders four other Moroccan regions (30°54'N, 5°36'W) (Figure 1). This region is dominated by oasis areas 88%, integrating five provinces, including Ouarzazat, Zagora, Tinghir, Errachidia, and Midelt. This latter is known for its apple culture, occupying 39% of national superficies with 60% of national apple production [18,19]. The Fez-Meknes region, located in the north of Draa -Tafilalet (34°02'00 "N, 500'00" W), this region is composed of provinces and prefectures of Fez, Meknes, Boulemane, Sefrou, Moulay-Yacoub, Taounate, Taza, Elhajeb, and Ifrane, the provinces of Sefrou and Boulmane are well known for their apple culture allowing the creation of numerous cooperatives producing apple by-products.

2.2. Data collection.

The main objective of this survey is to enlighten the traditional Moroccan knowledge of apple vinegar that people of the two largest apple-growing areas use to handle their different ailments according to their practice and experience. An ethnopharmacological survey was performed in 2018 in the two Moroccan regions mentioned above. The questionnaire focused on information about each informant, gender, education profile, and age tranche. We collected information about the traditional use of apple vinegar, doses used, affections treated, and degree of satisfaction.

2.3. Data analysis.

The questionnaire data were entered in MS Windows Excel in codes and then statistically analyzed by the SPSS software version 21.

3. Results and Discussion

3.1. Socio-demographic information of respondents.

Figure 1 displays the socio-demographic information of respondents. It is seen that women represent the highest percentage of interviewed people, with a percentage of 62%,

while 38% of all respondents are men. This is the case of numerous ethnopharmacological studies performed in different Moroccan territories [20,21]. Furthermore, women's function in rural communities allows them to develop their traditional knowledge of natural products to manage multiple disorders as a cultural patrimony transmitted from generation to generation [20]. The age range of all respondents was: those aged between 20-30 (75%), followed by those aged more than 30 (18%), and those aged under 20 (7%). In other studies, the oldest people represent the largest group with vast traditional knowledge [22]. The reorientation towards natural products reinforces their traditional use among young people. Most of the persons who participated in this survey attended the university with a frequency of 82%, 8% attended the secondary level, 6% were illiterate, and 4% attended the primary level. A high percentage of apple vinegar users attended university, which permits them to get more information about the traditional uses of apple vinegar from different research engines. Additionally, it has been shown that the most source of traditional knowledge is the transmission of how-know from one generation to another [21,23].

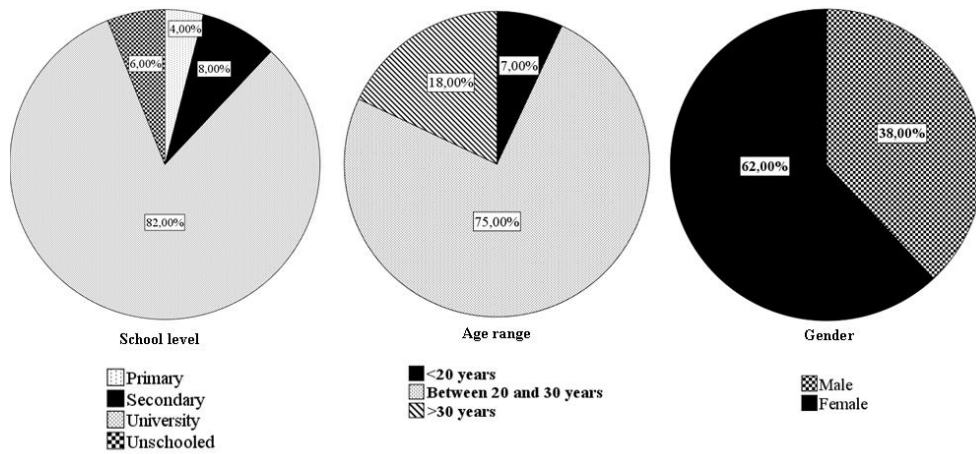


Figure 2. Information of the interviewed persons.

3.2. Uses of apple vinegar.

Figure 3 resumes the distribution of users and non-users of apple vinegar and its uses mentioned by all respondents in their questionnaire responses.

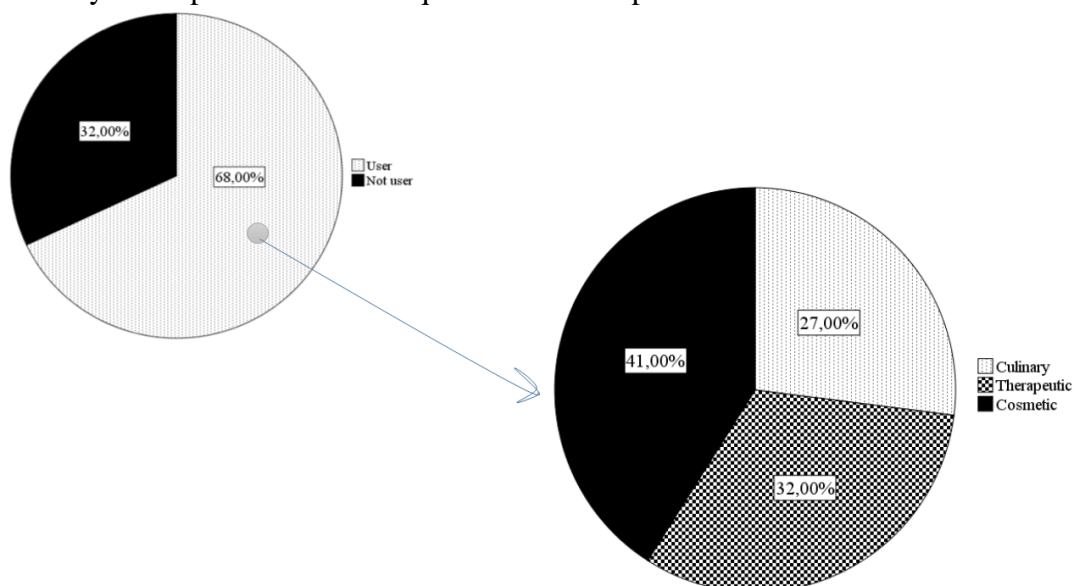


Figure 3. Distribution of users and non-users and different utilizations of apple vinegar.

The treatment of all data collected revealed that among the 200 interviews, 68% declared that they use apple vinegar in their daily habits. While 32% declared they did not use this product. Different reports documented that several civilizations widely use apple vinegar for many purposes [2]. The transmission of traditional knowledge from one generation to another permit preserving this culture across time [24]. In addition, it has been considered the keystone of several experimental studies that designed different protocols to confirm the beneficial properties of natural products in ancient traditional books [12].

The analysis of results showed that apple vinegar has multifaceted use. 41% of all users declared that they use this product for cosmetic purposes, while 32% and 27% mentioned that apple vinegar was used for therapeutic and culinary purposes, respectively. Apple vinegar is considered a necessity of each household, as previously documented by Berry [25]. It has been proven that this product is used to maintain and preserve food quality, color, condiments, and healthy drinks [26]. Mounting scientific evidence showed that apple vinegar exhibited a wide spectrum of beneficial properties, including antioxidant, anti-melanogenic, anti-cellulite, Seboregulatory, and anti-inflammatory effects [27–30]. Thanks to its complex phytochemical composition, apple vinegar exhibits several biological properties but is still a promising product and gained the scientific community's interest to highlight its undiscovered activities.

3.3. Traditional medicinal applications of apple vinegar.

Figure 4 displays different pathologies treated traditionally by apple vinegar according to the interviewed people of both regions under study in Morocco. The treatment results revealed that the pathologies affecting the digestive system are on the top list of ailments treated using apple vinegar (42%). In secondary, the ailments of integumentary systems ranked in the second group with a proportion of 33%, while cardiovascular, genitourinary, neuropsychic, and respiratory diseases represented 8%, 6%, 6%, and 5%, respectively.

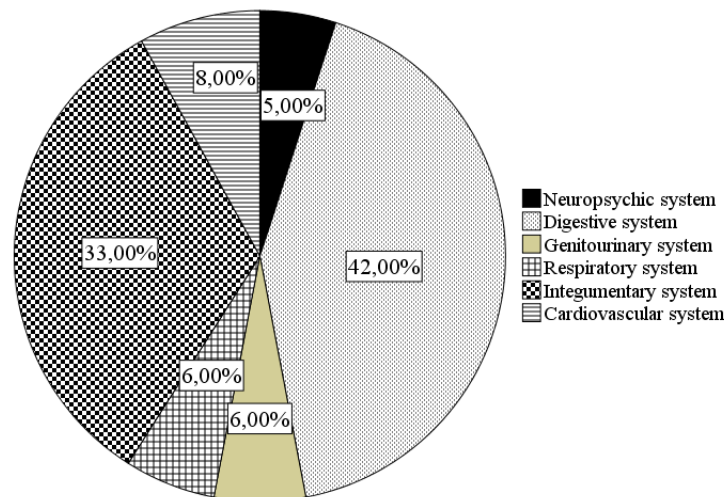


Figure 4. Distribution of different systems treated traditionally with apple vinegar.

The beginning of the traditional use of vinegar probably accompanied the discovery of the fermentation process. Egyptians named vinegar HmD or hemedj and figured it out in the Instruction of Ankhsheshonq [2]. It is probably the first antibiotic used to eradicate different pathogenic microorganisms [31]. Additionally, the father of medicine (Hippocrates) described vinegar as a natural medication for his patients to handle their ailments accounting for wound dressing [31]. Numerous scientific evidence confirms the utility of apple vinegar to treat and

prevent a wide broad of diseases, including metabolic disorders [15], obesity [5], oxidative stress [32], Alzheimer's [33], cancer [34], pathogenic bacteria [35,36], and inflammation [29,30]. Apple vinegar has beneficial properties throughout the pleiotropic effect due to its dense and diverse phytochemical composition [37].

3.4. Duration of treatment with apple vinegar

The posology of treatment with apple vinegar depends on the disease treated. Figure 5 displays the results of the duration of treatment. The most interviewed people declared that they used apple vinegar for one week (28%), followed by the proportion of people who used it until complete healing (27%). The rest were either day (25%) or a month (20%) of treatment. No document reported any sign of toxicity or negative side effect. In the same context, numerous studies tested high amounts of vinegar, and none documented any negative side effects [26]. At the same time, the uncontrolled practice or improper use of apple vinegar could be induced intoxication or adverse effects.

Similarly, Bounihi et al. found that administering high doses of apple vinegar (14mL/kg/day) for 18 weeks did not induce any sign of toxicity, side effects, or lethality [6].

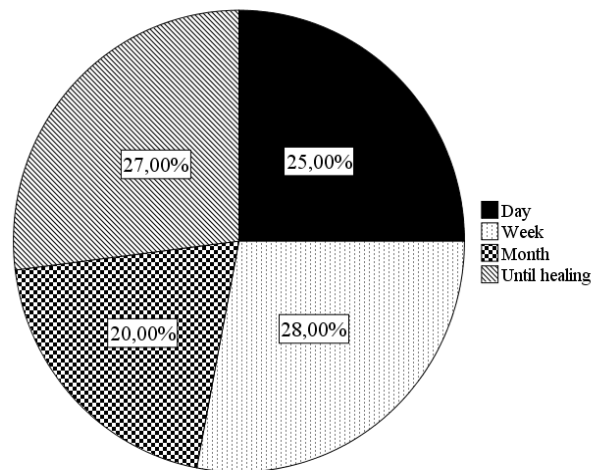


Figure 5. Duration of treatment with apple vinegar.

3.5. Degree of satisfaction.

Figure 6 displays the degree of satisfaction of different users of apple vinegar who participated in preparing this work. The treatment of the obtained results showed that 60% of users think that the administration of apple vinegar improved their health after treatment, and 19% declared that this product achieved the complete healing of the treated disease. In contrast, 14% and 7% of users of apple vinegar reported the appearance of side effects and intoxication, respectively. Several studies on animals and humans have been carried out to demonstrate the beneficial properties of apple vinegar [26]. Mounting scientific evidence showed that apple vinegar contracts different pathologies such as diabetes, pathogenic bacteria, obesity, cancer, inflammation, Alzheimer, and blood pressure [38,39]. To the best of our knowledge, there is no report documenting the side effects of the toxicity of apple vinegar.

4. Conclusions

In conclusion, this study repertory in particularly useful knowledge of how apple vinegar was used by the population of two Moroccan largest apple-growing regions (Fez-

Meknes and Deraa-Tafilelt), which could enrich the Moroccan database about medicinal plants and their biological effects. At the same time, more experiments are required to provide a complete view of traditional knowledge and examine apple vinegar's biological effects.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Ashworth, M.; Cloatre, E. Enacting a Depoliticised Alterity: Law and Traditional Medicine at the World Health Organization. *International Journal of Law in Context* **2022**, 1–23, <https://www.cambridge.org/core/journals/international-journal-of-law-in-context/article/enacting-a-depoliticised-alterity-law-and-traditional-medicine-at-the-world-health-organization/6710F274D78B38024CF4ABA207BDF210>.
2. Mazza, S.; Murooka, Y. Vinegars through the Ages. In *Vinegars of the world*; Springer, **2009**; 17–39, https://link.springer.com/chapter/10.1007/978-88-470-0866-3_2.
3. Solieri, L.; Giudici, P. Vinegars of the World. In *Vinegars of the World*; Solieri, L., Giudici, P., Eds.; Springer Milan: Milano, **2009**; 1–16, <https://link.springer.com/book/10.1007/978-88-470-0866-3>.
4. Ozturk, I.; Caliskan, O.; Tornuk, F.; Ozcan, N.; Yalcin, H.; Baslar, M.; Sagdic, O. Antioxidant, Antimicrobial, Mineral, Volatile, Physicochemical and Microbiological Characteristics of Traditional Home-Made Turkish Vinegars. *LWT - Food Science and Technology* **2015**, *63*, 144–151, <https://doi.org/10.1016/j.lwt.2015.03.003>.
5. Bouazza, A.; Bitam, A.; Amiali, M.; Bounihi, A.; Yargui, L.; Koceir, E.A. Effect of Fruit Vinegars on Liver Damage and Oxidative Stress in High-Fat-Fed Rats. *Pharmaceutical biology* **2016**, *54*, 260–265, <https://doi.org/10.3109/13880209.2015.1031910>.
6. Bounihi, A.; Bitam, A.; Bouazza, A.; Yargui, L.; Koceir, E.A. Fruit Vinegars Attenuate Cardiac Injury via Anti-Inflammatory and Anti-Adiposity Actions in High-Fat Diet-Induced Obese Rats. *Pharmaceutical biology* **2017**, *55*, 43–52, <https://doi.org/10.1080/13880209.2016.1226369>.
7. Theapparath, Y.; Chandumpai, A.; Faroongsarng, D. Physicochemistry and Utilization of Wood Vinegar from Carbonization of Tropical Biomass Waste. *Tropical Forests - New Edition* **2018**, <https://doi.org/10.5772/intechopen.77380>.
8. Thinathayalan, D.; Yuan, B.T.K.; Kaur, J.; Albert, Y.; Yan, N.J. The Effects of Apple Cider Vinegar on Weight, Blood Pressure, Blood Glucose Level and Heart Rate of 60 MMMC Medical Students Randomized Controlled Trial. *Medicine Journal* **2019**, *6*, 88, <http://www.openscienceonline.com/journal/archive2?journalId=720&paperId=4963>.
9. Tripathi, S.; Mazumder, P.M. Apple Cider Vinegar (ACV) and Their Pharmacological Approach towards Alzheimer's Disease (AD): A Review. *Indian J. Pharm. Educ. Res* **2020**, *54*, s67–s74, <https://www.ijper.org/sites/default/files/IndJPhaEdRes-54-2s-67.pdf>.
10. Tripathi, S.; Mazumder, P.M. Neuroprotective Efficacy of Apple Cider Vinegar on Zinc-High Fat Diet-Induced Mono Amine Oxidase Alteration in Murine Model of AD. *Journal of the American College of Nutrition* **2021**, 1–10, <https://doi.org/10.1080/07315724.2021.1948933>.
11. Tripathi, S.; Mitra Mazumder, P. Comprehensive Investigations for a Potential Natural Prophylaxis—A Cellular and Murine Model for Apple Cider Vinegar against Hydrogen Peroxide and Scopolamine Induced Oxidative Stress. *Drug Dev Res* **2021**, ddr.21849, <https://doi.org/10.1002/ddr.21849>.
12. Süntar, I. Importance of Ethnopharmacological Studies in Drug Discovery: Role of Medicinal Plants. *Phytochemistry Reviews* **2020**, *19*, 1199–1209, <https://link.springer.com/article/10.1007/s11101-019-09629-9>.
13. Attique, S.A.; Hassan, M.; Usman, M.; Atif, R.M.; Mahboob, S.; Al-Ghanim, K.A.; Bilal, M.; Nawaz, M.Z. A Molecular Docking Approach to Evaluate the Pharmacological Properties of Natural and Synthetic Treatment Candidates for Use against Hypertension. *International journal of environmental research and public health* **2019**, *16*, 923, <https://doi.org/10.3390%2Fijerph16060923>.
14. Fu, Y.-S.; Chen, T.-H.; Weng, L.; Huang, L.; Lai, D.; Weng, C.-F. Pharmacological Properties and Underlying Mechanisms of Curcumin and Prospects in Medicinal Potential. *Biomedicine & Pharmacotherapy* **2021**, *141*, 111888, <https://doi.org/10.1016/j.biopha.2021.111888>.

15. Ousaaid, D.; Laaroussi, H.; Bakour, M.; ElGhouizi, A.; Aboulghazi, A.; Lyoussi, B.; ElArabi, I. Beneficial Effects of Apple Vinegar on Hyperglycemia and Hyperlipidemia in Hypercaloric-Fed Rats. *Journal of Diabetes Research* **2020**, 2020, <https://doi.org/10.1155/2020/9284987>.
16. Ousaaid, D.; Laaroussi, H.; Bakour, M.; El Ghouizi, A.; El Menyiy, N.; Lyoussi, B.; El Arabi, I. Effect of a Combination of Rosa Canina Fruits and Apple Cider Vinegar against Hydrogen Peroxide-Induced Toxicity in Experimental Animal Models. *Journal of Food Quality* **2022**, 2022, e7381378, <https://doi.org/10.1155/2022/7381378>.
17. Omar, N.A.A.; Ayat, M.M.A.; Shafik, S.R.; Elshweikh, S.A.; Sayed, S.M.E. Apple Cider Vinegar (A Prophetic Medicine Remedy) Protects against Nicotine Hepatotoxicity: A Histopathological and Biochemical Report. *American Journal of Cancer Prevention* **7**, **2015**, *3*, 122-127, <http://www.sciepub.com/AJCP/abstract/5450>.
18. Ousaaid, D.; Laaroussi, H.; Badiaa, L.; Elarabi, I. Physicochemical Properties and Antioxidant Activity of Two Varieties of Apple Cultivated in Different Areas in Morocco. *Mediterranean Journal of Chemistry* **2020**, *10*, 371–377, <https://doi.org/10.13171/mjc10402004271380do>.
19. SIAM, S. Agriculture : La production de pommes au Maroc s'élève à 697 000 tonnes – SIAM 15ème Édition 2020 | Salon International de l'Agriculture au Maroc **2019**, <https://www.salon-agriculture.ma/agriculture-la-production-de-pommes-au-maroc-seleve-a-697-000-tonnes/>.
20. Es-Safi, I.; Mechchate, H.; Amagnouje, A.; Jawhari, F.Z.; Bari, A.; Cerruti, P.; Avella, M.; Grafov, A.; Bousta, D. Medicinal Plants Used to Treat Acute Digestive System Problems in the Region of Fez-Meknes in Morocco: An Ethnopharmacological Survey. *Ethnobotany Research and Applications* **2020**, *20*, 1–14, <https://ethnobotanyjournal.org/index.php/era/article/view/2201>.
21. Mechchate, H.; Es-safi, I.; Bari, A.; Grafov, A.; Bousta, D. Ethnobotanical Survey about the Management of Diabetes with Medicinal Plants Used by Diabetic Patients in Region of FezMeknes, Morocco. *Journal of ethnobotany research and applications* **2020**, <https://ethnobotanyjournal.org/index.php/era/article/view/1783>.
22. Birjees, M.; Ahmad, M.; Zafar, M.; Nawaz, S.; Jehanzeb, S.; Ullah, F.; Zaman, W. Traditional Knowledge of Wild Medicinal Plants Used by the Inhabitants of Garam Chashma Valley, District Chitral, Pakistan. *Acta Ecologica Sinica* **2022**, *42*, 19–33, <https://doi.org/10.1016/j.chnaes.2020.12.006>.
23. Benkhniq, O.; Ben Akka, F.; Salhi, S.; Fadli, M.; Douira, A.; Zidane, L. Catalogue Des Plantes Médicinales Utilisées Dans Le Traitement Du Diabète Dans La Région d'Al Haouz-Rhamna (Maroc). *J Anim Plant Sci* **2014**, *23*, 3539–3568, <https://www.m.elewa.org/JAPS/2014/23.1/4.pdf>
24. Fletcher, M.-S.; Hamilton, R.; Dressler, W.; Palmer, L. Indigenous Knowledge and the Shackles of Wilderness. *Proceedings of the National Academy of Sciences* **2021**, *118*, e2022218118, <https://www.pnas.org/doi/10.1073/pnas.2022218118>.
25. Berry, B. Le Marché Mondial Du Vinaigre: Possibilités Pour Les Exportateurs Canadiens de Vinaigre Agri-Réseau | Documents, https://www.agrireseau.net/marketing-agroalimentaire/documents/marche_vinaigre_.pdf.
26. Launholt, T.L.; Kristiansen, C.B.; Hjorth, P. Safety and Side Effects of Apple Vinegar Intake and Its Effect on Metabolic Parameters and Body Weight: A Systematic Review. *European journal of nutrition* **2020**, 1–17, <https://doi.org/10.1007/s00394-020-02214-3>.
27. CUETO, M.S.; CASTAÑEDA, A.Z. Design and Evaluation of Cosmetics with Apple Vinegar and Extract. *EDICIONES UNIVERSIDAD DE SALAMANCA* **2019**, *4*, https://gredos.usal.es/bitstream/handle/10366/141717/Diseno_y_evaluacion_de_cosmeticos_con_vinaigre.pdf;jsessionid=F608C22066024F012ED801418BEF10A9?sequence=1.
28. KALABA, V.; BALABAN, Ž.M.; KALABA, D. ANTIBACTERIAL ACTIVITY OF DOMESTIC APPLE CIDER VINEGAR. *AGROFOR* **2019**, *4*, http://agrofor.ues.rs.ba/data/20190214-03-kalaba_et_al.pdf.
29. Song, J.; Zhang, J.; Su, Y.; Zhang, X.; Li, J.; Tu, L.; Yu, J.; Zheng, Y.; Wang, M. Monascus Vinegar-Mediated Alternation of Gut Microbiota and Its Correlation with Lipid Metabolism and Inflammation in Hyperlipidemic Rats. *Journal of Functional Foods* **2020**, *74*, 104152, <https://doi.org/10.1016/j.jff.2020.104152>.
30. Meng, H.; Song, J.; Fan, B.; Li, Y.; Zhang, J.; Yu, J.; Zheng, Y.; Wang, M. Monascus Vinegar Alleviates High-Fat-Diet-Induced Inflammation in Rats by Regulating the NF-κB and PI3K/AKT/MTOR Pathways. *Food Science and Human Wellness* **2022**, *11*, 943–953, <https://doi.org/10.1016/j.fshw.2022.03.024>.
31. Conner, H.A.; Allgeier, R.J. Vinegar: Its History and Development. In *Advances in Applied Microbiology*; Elsevier, **1976**; *20*, 81–133, [https://doi.org/10.1016/S0065-2164\(08\)70110-2](https://doi.org/10.1016/S0065-2164(08)70110-2).
32. Öztürk, A.; Özdemir, Y.; Göksel, Z. Apple Vinegar and Its Therapeutic Effects. *TABAD, Tarım Bilimleri Aras< tail> trma Dergisi* **2009**, *2*, 155–158.
33. Tripathi, S.; Mazumder, P.M. Apple Cider Vinegar (ACV) and Their Pharmacological Approach towards Alzheimer's Disease (AD): A Review. *Indian Journal of Pharmaceutical Education and Research* **2020**, *54*, s67–s74, <https://www.ijper.org/sites/default/files/IndJPhaEdRes-54-2s-67.pdf>.
34. Kaya, M.M.; Tutun, S.; Usluer, M.S.; Tutun, H. Investigation of Antiproliferative Effects of Home-Made and Commercial Apple Vinegars on Myeloma Cells. *Turkish Journal of Agriculture-Food Science and Technology* **2021**, *9*, 2173–2178, <http://agrifoodscience.com/index.php/TURJAF/article/view/4416>.

35. Ousaaïd, D.; Imtara, H.; Laaroussi, H.; Lyoussi, B.; Elarabi, I. An Investigation of Moroccan Vinegars: Their Physicochemical Properties and Antioxidant and Antibacterial Activities. *Journal of Food Quality* **2021**, *2021*, <https://doi.org/10.1155/2021/6618444>.
36. Ousaaïd, D.; Laaroussi, H.; Bakour, M.; Ennaji, H.; Lyoussi, B.; El Arabi, I. Antifungal and Antibacterial Activities of Apple Vinegar of Different Cultivars. *International Journal of Microbiology* **2021**, *2021*, <https://www.hindawi.com/journals/ijmicro/2021/6087671/>.
37. Ousaaïd, D.; Laaroussi, H.; Bakour, M.; El Ghouizi, A.; Mechchate, H.; Es-safi, I.; Conte, R.; Lyoussi, B.; El Arabi, I. New Insights Into Phytochemical Content and Antioxidant Activities of Moroccan Fruit Vinegars. *Chemistry Africa* **2022**, <https://doi.org/10.1007/s42250-022-00427-z>.
38. Budak, N.H.; Aykin, E.; Seydim, A.C.; Greene, A.K.; Guzel-Seydim, Z.B. Functional Properties of Vinegar. *Journal of Food Science* **2014**, *79*, R757–R764, <https://doi.org/10.1111/1750-3841.12434>.
39. Chen, H.; Chen, T.; Giudici, P.; Chen, F. Vinegar Functions on Health: Constituents, Sources, and Formation Mechanisms. *Comprehensive Reviews in Food Science and Food Safety* **2016**, *15*, 1124–1138, <https://doi.org/10.1111/1541-4337.12228>.