



## Donkey Milk in Cosmetics and Therapeutic Applications: An Updated Review

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### Abstract

In cosmetics, donkey milk is used for its cleaning and hydrating action combined with an antioxidant action that prevents the aging. Donkey milk is known for its restorative properties, aiding in the reduction of fine lines and regeneration of damaged skin cells. The proteins and lipids present in donkey milk contribute to skin nourishment, enhanced elasticity, and reduced wrinkle appearance. In cosmetics, donkey milk, rich in nutrients, possesses antioxidant and moisturizing properties, making it an ideal ingredient in cosmetic formulations such as creams, lotions, and soaps. The increasing awareness of skin care among the younger generation, coupled with the belief in natural and organic products, fuels the demand for donkey milk in cosmetics. Donkey milk, a natural and eco-friendly ingredient, is free from synthetic chemicals and additives, making it an attractive option for cosmetic manufacturers. This segment's expansion also includes the incorporation of donkey milk in hair care products, like shampoo conditioners. Innovation in the cosmetics and personal care sector, such as the development of new donkey milk-based products and formulations, further propels market growth. Furthermore, the cosmetics industry's growing focus on anti-aging products is driving the demand for donkey milk, which is known for its anti-inflammatory and anti-aging properties.

**Keywords:** Anti-Aging; Anti-Inflammatory; Cosmetics; Cow Milk Protein Allergy (CMPA); Donkey Milk; Skin Care

### 1. Introduction

Donkey milk has lower content of fat, protein and inorganic salts, and higher content of lactose in comparison to bovine milk [1-66-155]. The results of evaluation of whitening activities *in vitro* and *in vivo* indicated that donkey milk had a potent inhibitory effect on melanin synthesis [1-66-155]. Donkey milk contains various immunological factors such as lysozyme, lactoferrin, omega-3 fatty acids, bioactive peptides and immunoglobulins (IgA, IgG, and IgM) [1-66-155]. In cosmetics, donkey milk, rich in nutrients, possesses antioxidant and moisturizing properties, making it an ideal ingredient in cosmetic formulations such as creams, lotions, and soaps [1-66-154]. Donkey milk is known for unique nutritional composition and potential biological activities [1-66-155]. The percentage of essential amino acids, protein and lipid profiles similar to those of human milk favor donkey milk as a potential new dietetic food and a good alternative for infant nutrition in the case of cow's milk protein allergy (CMPA) [1-66-155]. Donkey milk may benefit overall skin health and cure some skin diseases because donkey milk is rich in vitamin A, vitamin C, niacin, phosphorus, magnesium, zinc, glycine, glutamic acid,  $\omega$ 3-polyunsaturated fatty acids, lipidic prostaglandins, leukotrienes, all of which occur in pharmaceuticals and cosmetics [1-66-135-154]. Until now, the anti-photo damage activities of donkey milk, especially skin barrier protection and melanin production inhibitory activities has not been reported [1-66-155].

Donkey milk (DM), as a valid natural substitute for cow milk, is similar to human milk in chemical components and organoleptic characteristics, which draws attention [1-66-154]. To our knowledge, no allergic reaction to donkey milk

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has been reported so far. It is said that Cleopatra took donkey milk for a shower to lighten the skin around 3,000 years ago [1-66-152]. Many milk compositions have shown promise in preclinical studies and have been undergoing active clinical trials [1-66-153]. Overall, donkey milk has considerable potential as a functional ingredient in food, cosmetic and pharmaceutical application [1-66-152]. Donkey milk helps the skin restore after UVB exposure [1-66-155]. The whitening effect was mainly reflected in the good inhibitory effect of donkey milk on synthesis of melanin, tyrosinase activity, and related gene expression [1-66-155]. Donkey milk could not only prevent UVB-induced adverse effects but also restore skin barrier function by increasing FLG's expression and regulating metabolism procedures such as lipid and steroid metabolism [1-66-153]. Hence, donkey milk is desirable for skin care cosmetics against UVB-induced skin barrier damage and melanin pigmentation [1-66-155].

The proteins and lipids present in donkey milk contribute to skin nourishment, enhanced elasticity, and reduced wrinkle appearance [119-152]. Donkey milk has antiallergic, antimicrobial, antifungal, antibacterial, hypoglycemic, anti-oxidative, antiviral, antiinflammatory, antiparasitic, antitumor activities and immunomodulating properties, which are beneficial to human health [1-66-155]. Donkey milk has a lot of unsaturated fatty acids especially linoleic acid, and low content of fat and cholesterol, is rich in calcium and selenium [1-66-155]. Donkey milk also has strong antioxidant activity, retarding aging process, and is rich in kinds of immune-boosting substances to human immune system [1-66-153]. It is rich in all the micro nutrients namely B-group of vitamins such as thiamine, riboflavin, niacin, pyridoxine, and folic acid [1-66-152]. Despite these promising attributes, the donkey milk industry faces challenges including low milk yield, lack of standardized production methods, and quality control measures [1-66-155]. In the following section, the role of donkey milk in cosmetic industry has been updated and discussed.

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## 2. Therapeutic Applications and Health Benefits

Donkey milk is highly appreciated for its low energy value, higher content of polyunsaturated fatty acids, essential amino acids and lactose content compared to other (human, bovine and buffalo) milks [1-66-118]. So far, different new age dairy products such as fermented emulsions, beverages and probiotic beverages, kefir, soft and hard variants of cheese, ice-cream and powder have been developed from donkey milk [1-66-112]. Donkey milk has been reported to be good for the patients suffering with cardiovascular diseases and diabetes [1-66-97-112]. Donkey milk can be a functional ingredient for human diet in form of functional drinks, beverages or other fermented and non-fermented dairy product(s) [1-76]. It can be utilized as the best alternative to cattle milk protein allergic population [1-76-153].

It is rich in all the micro nutrients namely B-group of vitamins such as thiamine, riboflavin, niacin, pyridoxine, folic acid [1-66-100]. However, people's intolerance and allergic reactions to cow's milk (CM) have led to a rising demand for alternative milk sources in recent years such as horse and donkey milk [1-66-100]. Furthermore, donkey milk is classified as a "pharma food" that is also highly preferred by consumers [1-155]. Nowadays, the economic worth of donkey milk has been recognized not only for its nutritional value but also for its medicinal and functional capacities due to its chemical composition, which is similar to human milk, particularly for newborns with cow's milk protein allergy [1-152]. It has a hypo-allergenic protein composition, high polyunsaturated fatty acid (PUFA), and essential amino acid [1-100]. In addition, donkey milk exhibited antiaging, antioxidant, antibacterial, anti-inflammatory, and antiaggregant activities related to its unique composition [1-100]. Due to its compositional specificity, it affects the properties of formulated products and affects fermentation and cheese making process [1-96]. Furthermore, lysozyme present in the donkey milk possesses potential antimicrobial properties against range of microorganisms [1-106]. The native constituents present in cow milk (CM) have been reported to adversely affect the consumer's health with disorders like milk protein allergy (MPA) and lactose intolerance [1-86]. Donkey milk is now emerging as a better option for the persons suffering from milk protein allergy (MPA) [1-66-106]. The casein to whey protein (WP) ratio of donkey milk is quite comparable to that of human milk, but quite lower compared to cattle milk [1-70-112]. Thus, donkey milk can be used as a substitute to human milk for infant nutrition and milk protein allergy [1-66]. Hence, donkey milk possesses lower cholesterol, casein to whey protein ratio, higher Ca to P ratio and **taurine** content than bovine milk [1-66-110].

Therapeutic and functional properties of donkey milk had been well documented and its use in treating various diseases i. e., asthma, bronchitis, gastritis and joint pain [1-66-112]. Several studies have reported the presence of somatic cells, food borne pathogens and bacteria in raw donkey milk, but in lower numbers as compared to cattle and buffalo milk [1-96]. Functional and health promoting attributes of donkey milk in terms of infant nutrition, cholesterol reduction, hypertension minimization, antimicrobial, immunomodulating activities and hypoallergenicity have been reported [1-66-106]. Donkey milk **kefir** contains less dry matter, fat, and protein. However, it is richer in lactose than cow milk kefir [1-66-106-155]. The microbiological profile reveals a low number of germs and an absence of pathogenic germs in kefir, particularly for donkey milk kefir. Indeed, the microbial profile of kefir was improved during storage [1-66-100]. The evaluation of the antioxidant and antibacterial activities of kefir shows a significant improvement during storage

[1-66-109]. Sensorial results showed that raw donkey milk is the most appreciated sample. While the fermentation of milk with kefir grains stored for 48 h has improved the appreciation of color, flavor, smell, taste, and texture [1-66-112]. Thus, donkey kefir production could be a good fermented product because of its composition and high antioxidant and antibacterial activities [1-66-112].

The functional properties of donkey milk like antimicrobial (against various pathogens), antitumor, antiproliferative, antioxidative, antihypertensive (ACE inhibitory) and their role in improving human health or preventing the onset of disease has been reviewed [1-66-152]. These health promoting effects have been largely attributed to the presence of a range of functional compounds like lactoferrin, lysozyme, bioactive peptides, oligosaccharides, immunoglobulins, etc. These potential nutraceutical properties have increased the use of donkey milk as functional food [1-66-155]. One of the study reported that donkey milk consumption improves the gastrointestinal condition of all age groups due to presence of natural antimicrobial and specific epidermal growth factors [1-100]. Demand of donkey milk is globally increasing because of its important nutritional characteristics, functional properties and pleasant sensory attributes [1-66-90]. It is currently gaining special research attention across the globe because of its chemical composition, functional and therapeutic properties [1-66-100]. However, the lower production of donkey milk is considered as one of the major problems in its processing on commercial scale. The mammary gland of donkey has lower capacity (less than 2.5 L). Per lactation yield of donkey milk (100–150 kg, 300 days lactation period) was markedly lower than that of cattle milk ( $8724 \pm 163$  per lactation (305 days) [1-66]. Donkey milk had a higher concentration of lysozyme (1.50 g/L) compared to cattle milk (0.0013 g/L) and human milk (0.42 g/L) [1-66-110-155]. Despite of the fact that lysozyme shows appreciable antimicrobial activity in milk, but its poor digestibility under in-vitro conditions has been reported [1-100]. The protein profile in donkey milk, in terms of casein, taurine content shows considerable differences making it a better choice for infant nutrition [1-106]. A considerable number of micronutrients (minerals and vitamins) and non-digestible oligosaccharides supplied by donkey milk aids in improving the human health and nutrition [1-96]. Donkey milk also contains several oligosaccharides that can play a pivotal role in bacterial metabolism in large intestine, as these oligosaccharides cannot be hydrolysed by enzyme(s) in the upper intestine and easily reach to the large intestine [1-99-154]. Nearly 200 different types of oligosaccharides are identified in human milk, but very limited study has been conducted on identification and quantification of oligosaccharides in donkey milk [1-99-154]. The literature available regarding the milk production and distribution of donkey milk is scanty; however, it is estimated that donkey milk accounts for 0.1 % of the entire world's milk production [1-76]. The global market size for donkey milk was valued to be USD 28,180 thousands in 2019 and is expected to reach USD 68,000 thousands by 2027 with CAGR of 9.4 % from 2021 to 2027 [1-100, 130, 131, 132].

Consumption of functional ingredients helps in improving the human health and aids in preventing the onset of diseases [1-105]. Products namely donkey milk powder, fermented products, cheese, ice cream etc. have been developed and characterized for their compositional, nutritional, functional and sensory attributes [1-66-155]. Owing to its low solids content i.e. casein, various group of authors have reported cheese manufacture from donkey milk as a challenging job [1-66-155]. Donkey milk contains components that promote the growth of bacteriocin-producing lactic acid bacteria [1-66-152]. *L. paracasei* and the bacteriocin is effective against several gut pathogens i.e., *Salmonella typhi*, *Pseudomonas aeruginosa*, and *E. coli* [1-112]. Antimicrobial protein fractions such as lactoferrin, lactoperoxidase and lysozyme present in donkey milk have demonstrated inhibition against wide range of bacteria and also help in minimization of gastrointestinal infections in digestive system [1-110]. The low initial microbial load in raw donkey milk, owing to higher concentration of lysozyme, makes it suitable for infant feeding, as it improves gastric conditions of children, minimizing or preventing the gastrointestinal infections [1-106-155].

Lysozyme has been reported to exhibit various functions like anti-inflammatory, anti-tumor, microbial inhibition activity and inactivate some of viruses [1-107-125]. Donkey milk antimicrobial activity was found to be most sensitive towards *Shigella dysenteriae* (CGMCC 1.1869) and *Salmonella choleraesuis* (CGMCC 1.1859) strain on study against nine microorganisms using agar diffusion assay [1-112]. While under in-situ conditions, donkey milk showed bactericidal activity against *S. dysenteriae* and reduced the viable count of the sample below the detection limit [1-112]. The antimicrobial activity of donkey milk's lysozyme and lactoferrin was assessed in Kashar cheese [1-112]. Cheese samples dipped in antimicrobial solution containing lysozyme and lactoferrin showed lower bacterial count compared to control sample [1-112]. The lysozyme isolated from donkey milk has shown its ability to prevent late blowing defect in Italian cheese by inhibiting spore forming clostridia, thus it can be best suited as an alternative to egg lysozyme in cheese manufacturing [1-112]. Donkey milk contains antitumor and anti-proliferative bioactive peptides and the most effective whey protein fraction (IV) of >10 kDa showed potent cytotoxicity and apoptosis by accumulation on A549 cells (human lung cancer cells) in G0/G1 and G2/M phases [1-112]. The anti-inflammatory properties of donkey milk in wound healing and cosmetic dermatology have also been revealed [1-66]. One of the study showed donkey milk, differentially expressed proteins exhibited immunoregulatory, antibacterial, antioxidative, promoting cell proliferation and skin moisture enhancement properties [1-66-112]. The presence of various functional ingredients in donkey milk contribute

to its various health promoting activities like antimicrobial as affected by the presence of lactoferrin, lysozyme, lactoperoxidase, presence of growth factors facilitating growth of bacteriocin producing lactic acid bacteria [1-66-112]. Appreciable antioxidant, ACE inhibitory peptides have been isolated from fermented donkey milk. In addition to this, significant antitumor, anti-proliferative and anti-inflammatory response has been well documented for donkey milk [1-66]. Supplementation of donkey milk with various non- dairy ingredients in combination with various probiotics or lactic acid bacterial cultures has also been practiced to improve the nutraceutical properties of donkey milk derived products [1-66-155]. In the nutshell, conversion of donkey milk into various value-added products requires extensive manipulation in the processing conditions owing to its altered composition in comparison to cattle milk or buffalo milk [1-155]. The composition of donkey milk is very much comparable to human milk which makes it fit for human consumption after proper heat treatment [1-66-155]. In addition, higher lactose content and presence of non-digestible oligosaccharides (pre- biotics) in donkey milk improves the intestinal health by promoting the growth of beneficial microflora inside the gut [1-66-109-155]. Application of different novel processing technologies like bioprocessing/fermentation, UV-C treatment, HPP and ultrasonication can be an alternative approach for manufacturing different dairy products so as to retain or improve the functional and nutritional properties of donkey milk [1-66-155].

### 3. Donkey milk in Cosmetic industries

The donkey milk market size is forecast to increase by USD 20.16 million at a CAGR of 9.64% between 2023 and 2028 [130, 131, 132]. The cosmetics and personal care segment is estimated to witness significant growth during the forecast period [130, 131, 132]. The market demand for donkey milk continues to grow, driven by its unique health benefits and nutritional profile [119-130, 131-155]. The market shows increasing demand, which indicates donkey milk will remain in commerce [119-130, 131-155]. Various brands will further develop the potential applications of donkey milk products [119-130, 131-142]. The cosmetic industry is likely to adopt donkey milk products from a donkey milk supplier like Ashva Donkey Farm as an essential element for daily skincare routines [119-130, 131-155]. In the dynamic global market for donkey milk, Europe holds a substantial share due to the escalating demand for natural ingredients in cosmetics and increasing consumer health consciousness [119-130, 131-155]. Countries like the UK, Germany, and Italy are major contributors, with the UK specifically seeing a surge in the use of donkey milk for maintaining wellness [119-130, 131-152]. Other European nations, including Spain, Portugal, Belgium, Bulgaria, Greece, and France, also consume donkey milk and related products [119-130, 131-155]. Factors fuelling market expansion include the rising imports of powdered donkey milk and evolving health preferences among consumers [130, 131, 132]. However, the market faces challenges in the form of the availability of substitutes for donkey milk, such as goat and cow milk, which may offer similar benefits at lower costs [130, 131, 135]. Donkey milk, a niche dairy product, is gaining popularity due to its potential health benefits [130, 131, 132]. With increasing consumer awareness and concern for nutrition, the demand for donkey milk is on the rise [130, 131, 132]. Protein content analysis and immunoglobulin levels are crucial factors in ensuring the quality of donkey milk [130, 131, 132]. As the demand for sugar-free products continues to surge, companies are expected to introduce sugar-free donkey milk variants to cater to this trend [130, 131, 132].

Exposure to ultraviolet (UV) radiation from sunlight accounts for a global rise in premature skin aging and skin cancer [119-155]. UV rays are separable into three types through wavelength: UVC is 200–280nm, UVA is 320–400nm and 280–320nm is UVB [119-152]. Since shorter UV wavelengths bring about more terrific impairment to the human body, the impairment induced by UVC is more pernicious than that caused by UVA and UVB [119-155]. UVC has been mostly absorbed by the ozone layer in the atmosphere. Therefore, UVB is the most dominant UV radiation for resulting in wrinkles, laxity, coarseness, and mottled pigmentation [119-155]. In the sunburn response, vasodilation and increased blood flow, endothelial cell activation, formation of “sunburn cells” (i.e., keratinocytes undergoing p53-dependent apoptosis), and release of inflammatory mediators occur in the epidermis and dermis before erythema and edema [119-152]. Pro-inflammatory cytokines, i.e., TNF- $\alpha$ , PGE2, PGE3, COX-2, IL-6, and IL-8, may play several roles in UVB-induced inflammation, including activation of transcription factors, upregulation of endothelial adhesion molecules, and recruitment of neutrophils to the skin [119-155].

Acute skin damage due to tanning manifests as sunburn [119-155]. Melanogenesis, on the other hand, may protect skin from the damages caused by UV irradiation [119-152]. Exposure to UV radiation, keratinocytes secrete an important melanogenesis regulator,  $\alpha$ -melanocyte stimulating hormones ( $\alpha$ -MSH), which may trigger the microphthalmia-associated transcription factor (MITF) activation through the melanocortin 1 receptor (MC1R) signaling pathway in melanocytes [119-152]. Then, the tyrosinase (TYR) activity and melanin production are subsequently upregulated in the melanosome [119-155]. Finally, melanin, which is produced and stored in melanocytes, is transferred to their attached keratinocytes. UVB-mediated pigmentation (delayed tanning) can also be triggered by an inflammatory cascade, suggesting that inflammation and sunburn are also important in the tanning response [119-152]. Furthermore, UV damage to the skin triggers inflammation that decreases the expression of genes associated with permeability

barrier repair [119-155]. Filaggrin (FLG), which is thought to be a major factor in the skin barrier, is reduced by sunburn [119-155]. During the past decade, safeguarding against UV radiation has been highly studied and was promoted in lots of public health education programs [119-155]. Researchers have frequently concentrated on how to forbid excessive UV exposure, and seldom pay attention to sunburn repairing, post-basking recovery, and pigmentation mechanisms [119-155].

Recently, two promising opportunities for the valorization of donkey milk have been discussed: innovative cheese production and use in cosmetic preparations [119-130, 131-155]. In cheese making, the lysozyme contained in donkey milk is a good alternative to egg-derived lysozyme, which can cause allergy symptoms in some consumers [119-130, 131-155]. In the cosmetics sector, the industry needs to constantly develop new products and improve its existing ones to stay ahead in a highly competitive market by obtaining information on consumer preferences [119-130, 131-152]. The use of anti-age cosmetics has become increasingly popular among consumers interested in natural skin care products [119-130, 131-155]. In fact, the cosmetics trade mainly focuses on products with natural ingredients without added preservatives, prompting many companies to increase the use of natural ingredients in existing or new products [119-130, 131-155]. Donkey milk in the cosmetic industry highlights its potential benefits, including its moisturizing, antioxidant, and antimicrobial properties, and investigate consumer perceptions and market viability [119-130, 131-155].

The facial area of the skin is easily exposed to many external factors such as environmental stress and UV radiation with relevant consequents [119-130, 131-155]. Generally, the skin elasticity decreases due to ageing, sun exposure, and dehydration. Due to their natural origin, milk components fulfil the requirements of the cosmetics sector in many areas [119-130, 131-152]. The proteins and other components contained in milk have a high absorption capacity and a strong water-binding capacity, thus promoting high hydration of the skin and preventing the degradation of epidermal cells [119-130, 131-152]. In addition, milk proteins with a glycosylated component could be widely used in any products developed to mitigate skin ageing [119-130, 131-155]. For example, lactoferrin, which is known to have a high iron chelating property, could prevent the formation of free radicals in the skin after prolonged sun exposure [119-130, 131-152]. There are several products on the cosmetics market that are made from milk of different species. Products made from cow's milk (face and body creams, cleansing milks, and tonics) are the best known among consumers [119-130, 131-152]. On the other hand, cosmetics made from the milk of other species such as camel, sheep, goat, mare, and donkey are little known and rarely [119-130, 131-155].

Regarding donkey milk, despite the historically recognized beautifying effects of donkey milk, few studies have been conducted on its perceived quality in cosmetics [119-130, 131-155]. The perception of untrained consumers regarding the sensory aspects of a face cream with added donkey milk has been discussed in many review papers [119-130, 131-152]. Milk and colostrum have high biological potential, and due to their natural origin and non-toxicity, they have many uses in cosmetics and dermatology [119-130, 131-155]. These natural products are especially rich in proteins, such as casein,  $\beta$ -lactoglobulin,  $\alpha$ -lactalbumin, lactoferrin, immunoglobulins, lactoperoxidase, lysozyme, and growth factors, and possess various antibacterial, antifungal, antiviral, anticancer, antioxidant, immunomodulatory properties, etc [119-130, 131-155]. Milk products are widely used in the treatment of dermatological diseases for promoting the healing of chronic wounds, hastening tissue regeneration, and the treatment of acne vulgaris or plaque psoriasis [119-130, 131-152]. They are also increasingly regarded as active ingredients that can improve the condition of the skin by reducing the number of acne lesions and blackheads, regulating sebum secretion, ameliorating inflammatory changes as well as bestowing a range of moisturizing, protective, toning, smoothing, anti-irritation, whitening, soothing, and antiaging effects [119-130, 131-155].

Furthermore, the cosmetics industry's growing focus on anti-aging products is driving the demand for donkey milk, which is known for its anti-inflammatory and anti-aging properties [119-130, 131-155]. However, the market faces challenges in the form of the availability of substitutes for donkey milk, such as goat and cow milk, which may offer similar benefits at lower costs [119-130, 131-155]. Donkey milk, a natural and eco-friendly ingredient, is free from synthetic chemicals and additives, making it an attractive option for manufacturers [119-130, 131-155]. Innovation in the cosmetics and personal care sector, such as the development of new donkey milk-based products and formulations, further propels market growth [119-130, 131-155]. This segment's expansion also includes the incorporation of donkey milk in hair care products, like shampoo conditioners [119-130, 131-152]. Antioxidant capacity, probiotic properties, and allergenic potential are essential aspects of donkey milk composition that add to its health benefits [119-155].

When evaluating a new cosmetic product, its effectiveness in improving the skin's moisturizing function as a barrier against water loss is the main factor assessed [119-155]. Studies have explored its use in skincare products like creams and lotions, focusing on its effects on skin barrier function, UV damage protection, and overall consumer

acceptability [1-121-152]. The research also points to its potential as a functional ingredient, especially for people with dry skin [1-121-155]. The use of donkey milk as a moisturizer in cosmetics is more fabulous [1-121-152]. In cosmetics, donkey's milk is used for its cleaning and hydrating action combined with an antioxidant action that prevents the aging [119-152]. In fact, the fat content in donkey's milk nourishes the skin and gives it softness [1-118-121-152]. Skin ageing is influenced by both intrinsic and extrinsic factors that promote the accumulation of physicochemical alterations in the cutaneous structure [1-121-155]. These alterations reveal themselves as clinical changes, including e.g. wrinkling, dyschromias and elastosis [121-155]. Ultraviolet (UV) radiation exposure, particularly UVA and UVB, is the major extrinsic ageing factor responsible for premature skin ageing [121-155].

Donkey milk is highly hydrating due to its protein-rich content, namely casein,  $\alpha$ -lactoalbumin and  $\beta$ -lactoglobulin and it contains traces of lactic acid, lactate and calcium, claimed to have positive effects on aged skin [119, 120, 121-155]. Donkey milk may have also contributed, in synergy with the pomegranate extract, to the increase in skin colour homogeneity due to the tyrosinase-inhibiting capacity of  $\alpha$ -lactoalbumin [119-130, 131-155]. In one of the study reported by BALTAZAR et al., (2017) [121], donkey milk was mixed with pomegranate extract and an optimized blend of UV filters in a cosmetic O/W emulsion [121]. The anti-ageing efficacy of this synergistic blend was assessed by imaging, biomechanical and electrometric methods on 32 volunteers, after 28 days of application [121]. The wrinkle count decreased by 32.9% and the wrinkle length was reduced by 9.6%. Skin hydration increased by 11.4%, while skin firmness and elasticity increased by 9.6% and 16.1%, respectively [19-121-155]. Furthermore, skin colour homogeneity was enhanced [121]. Thus, this product was proven to have antiageing effects, both by preventing photoageing and by diminishing existing signs of ageing [121]. In another study reported by Li et al., (2023) [119], donkey milk may have also contributed, in synergy with the pomegranate extract, to the increase in skin colour homogeneity due to the tyrosinase-inhibiting capacity of  $\alpha$ -lactoalbumin and the skin to restore after UVB exposure [119-152]. In this study, an in vitro test was conducted to reveal that donkey milk was protected against sunburn and tanning [119-143-155]. The whitening effect was mainly reflected in the good inhibitory effect of donkey milk on synthesis of melanin, tyrosinase activity, and related gene expression [119-143-155]. Donkey milk could not only prevent UVB-induced adverse effects but also restore skin barrier function by increasing FLG's expression and regulating metabolism procedures such as lipid and steroid metabolism [119-143-155]. Hence, donkey milk is desirable for skin care cosmetics against UVB-induced skin barrier damage and melanin pigmentation [119-143-152]. The use of donkey milk has a long history in external dermal application for cosmetic and medical purposes [120-143]. The patented creams exhibited satisfactory moisturizing properties very soon after application, while hydration was reached earlier in the spots treated with night cream [120-143-155]. In cosmetics, donkey's milk is used for its cleaning and hydrating action combined with an antioxidant action that prevents the aging [119-155]. In fact, the fat content in donkey's milk nourishes the skin and gives it softness [1-143-155]. Donkey milk is rich in vitamins and polyunsaturated fatty acids and contains anti-ageing, anti-oxidant and regenerating compounds, which are described as naturally active in skin hydration and skin ageing prevention [1-120-143-155].

The lack of viable alternatives to donkey milk poses a significant challenge to the expansion of the related industry [1-143]. Donkey milk faces competition from various alternatives in the global market, such as camel, goat, bovine milk, and plant-based milk. For instance, camel milk-based products, including powder, chocolates, and skincare items, offer superior health benefits and are increasingly used as ingredients in food and beverage manufacturing [1-143-155].

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#### 4. Conclusion

The donkey milk market size is forecast to increase by USD 20.16 million, at a CAGR of 9.64% between 2023 and 2028. Furthermore, the cosmetics industry's growing focus on anti-aging products is driving the demand for donkey milk, which is known for its anti-inflammatory and anti-aging properties. However, the market faces challenges in the form of the availability of substitutes for donkey milk, such as goat and cow milk, which may offer similar benefits at lower costs. Pasteurization methods and mineral concentration are critical factors in maintaining the probiotic properties of donkey milk, while milk processing techniques and digestibility testing contribute to product differentiation and value-added offerings. Quality control measures, supply chain logistics, and microbial contamination testing maintain economic viability and consumer trust. The market demand for donkey milk continues to grow, driven by its unique health benefits and nutritional profile. As such, supply chain logistics and farm management practices are continually evolving to meet the increasing demand. Donkey milk is desirable for skin care cosmetics against UVB-induced skin barrier damage and melanin pigmentation. Donkey milk remains a dynamic and innovative market, with new applications and value-added products continually emerging. The increasing interest in anti-aging cosmetics signifies a prominent market trend. This sector is experiencing significant growth due to the rising demand from consumers seeking to combat the signs of aging. Donkey milk, a natural source rich in essential fatty acids, vitamins, and minerals, is gaining popularity in the anti-aging cosmetics industry. The use of donkey milk as a moisturizer in cosmetics is more fabulous. Donkey milk is known for unique nutritional composition and potential biological activities. This beverage

from donkeys is known for its restorative properties, aiding in the reduction of fine lines and regeneration of damaged skin cells. The increasing awareness of skincare among the younger generation, coupled with the belief in natural and organic products, fuels the demand for donkey milk in cosmetics. Traceability systems and farm management practices are crucial in ensuring the quality of donkey milk. Proper packaging materials and supply chain logistics are essential to maintain the product's integrity during transportation and storage.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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