Indian Stream Research Journal
Vol -2 , ISSUE –X , Nov- 2012
ISSN No - 2230 - 7850
Available online at www.lbp.world

ORIGINAL ARTICLE

EFFECTS OF ULTRAVIOLET RADIATION (UV) IN DOMESTIC ANIMALS

Godwin Jacob D' Souza
Associate Professor , Dept. of Electronics,
St Joseph's College (Autonomous) Bangalore.

ABSTRACT:

Solar radiation is crucial for sustaining life on Earth, but environmental pollution exacerbates global climate change, contributing to the degradation of the atmospheric ozone layer. This layer is essential for regulating the type and amount of ultraviolet (UV) radiation that reaches the Earth's surface. Domestic animals are consistently exposed to direct solar radiation, which can lead to conditions such as skin lesions, ocular tumors, thermal stress, and even mortality. UV light induces oxidative stress in the skin by generating reactive oxygen species (ROS), which can harm cells, accelerating aging processes or increasing cancer risk. While antioxidants can mitigate these effects by neutralizing harmful agents, their effectiveness diminishes with age and metabolic state. A comprehensive review of skin histology, physiology, and the impacts of UV radiation on domestic animals was conducted using reputable bibliographic databases (such as PubMed/MEDLINE, Science) and accessible internet journals. Understanding these effects is critical as they can significantly impact producers financially, compromise animal welfare, and affect the quality and safety of animal-derived products.

KEY WORDS: Ultraviolet radiation, Domestic animals, Skin, Cancer.

INTRODUCTION

Solar energy is essential for all living beings on the planet. However, climate change, global warming, gas emissions, and the greenhouse effect have altered the atmosphere, which filters the sun's rays. These changes have affected the ozone layer, resulting in increased direct ultraviolet (UV) radiation reaching the Earth's surface. Environments and animal species exposed to direct solar radiation have been impacted, particularly livestock species. Excessive exposure to solar radiation can lead to skin lesions, optic tumors, heat stress, and even death in livestock, causing significant financial losses in the industry.

TYPES OF RADIATION

Radiation can be defined as energy that travels from one point to another, as well as energy that propagates in wave or particle form through space. The electromagnetic radiation emitted by the Sun is typically characterized by its frequency and wavelength (Figure 1) and can be classified based on two criteria:

BY ITS NATURE:

There are electromagnetic radiations(5,6), such as wave-propagated radiations (gamma rays, X-rays); ultraviolet radiations (UVA, UVB, UVC); visible radiation (violet, blue, green, yellow, orange, red);

infrared radiation; and radio frequencies (radar, microwave). And there are corpuscular radiations such as subatomic particles (α particles, β particles, neutrons, cosmic radiations); these move at high speeds and transport large amounts of energy(4,5,6).

BY ITS BIOLOGICAL EFFECT:

Radiation that carries enough energy to cause ionization in the mediums it crosses is known as ionizing radiation. In contrast, radiation that cannot separate electrons from atoms or alter molecular structures is called non-ionizing radiation. Although photon energy in non-ionizing radiation is too weak to break chemical bonds, it can still have biological effects such as heating and inducing electrical currents in tissues and cells. The classification of radiation as ionizing or non-ionizing is independent of its corpuscular or electromagnetic nature. Ionizing radiation includes alpha and beta particles, cosmic rays, gamma rays, X-rays, and a portion of the UV spectrum. Non-ionizing radiation examples include UV, visible, and infrared rays, as well as radio, TV, and mobile phone waves.

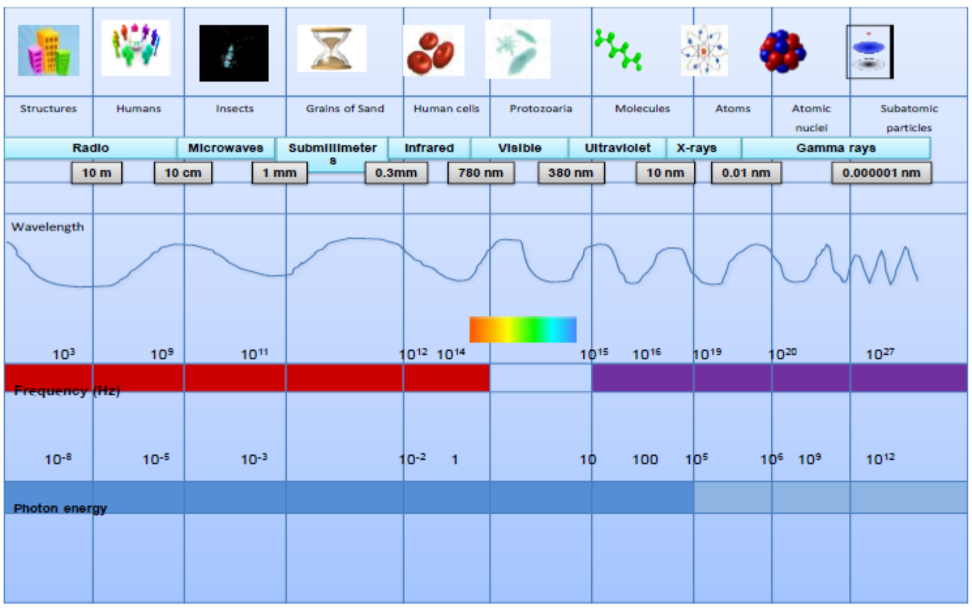

Figure 1: Electromagnetic radiation spectrum showing the different wavelengths emitted by the Sun (10)

ULTRAVIOLET (UV) LIGHT

Of the entire spectrum of solar radiation, only visible light (50%), infrared (40%), and part of the ultraviolet spectrum (10%) reach the planet's surface, with the remaining wavelengths being absorbed by stratospheric ozone. Ultraviolet solar radiation is defined as the power of UV solar energy per unit surface area (UV) and is measured in watts per square meter (W/m^2). It consists of three wavelength ranges: UVA (315-400 nm), UVB (280-315 nm), and UVC (100-280 nm). UVC radiation has the highest energy but is absorbed by the atmospheric ozone layer, as long as it remains intact, and thus does not have adverse effects on life forms. However, if the ozone layer were to degrade even slightly, UVC could begin to cause harmful effects.

Both the UVA (95%) and UVB (5%) spectra reach the Earth's surface, and exposure to them is a known risk factor for the development of skin cancer. UVB radiation contributes to the formation of photoproducts and other complexes that impair nucleic acids, leading to long-term consequences and various skin neoplasms caused by repeated or frequent burns on the epidermis. UVA radiation's cytotoxicity is mainly mediated by photosensitizing endogenous molecules, which absorb photons and generate reactive oxygen species, causing direct damage to the dermis and premature aging.

The atmosphere

The atmosphere is primarily composed of nitrogen (78%) and oxygen (21%). The remaining percentage consists of trace gases, including minute amounts of ozone at a concentration of no more than a few molecules per million air particles (0.01%). Despite its low concentration, ozone is crucial for preserving life on Earth because it protects living organisms from UV radiation, a significant physical carcinogen for both terrestrial and marine animals.

The ozone molecule, consisting of three oxygen atoms (O3), is mainly created in two regions of the atmosphere. Over 90% of ozone is found in the upper stratosphere, about 50 km above the Earth's surface, where it is essential for reflecting harmful radiation back into space. The remaining 10% is generated at surface level (the troposphere), particularly in large urban areas as a component of smog.

Since at least the mid-20th century, human activity has disrupted the ozone layer’s ecological balance by producing and emitting "ozone-depleting substances" (ODS) into the atmosphere. The most well-known ODS are chlorofluorocarbons (CFCs), which were used in the manufacture of aerosols, refrigerators, and air conditioning equipment until they were banned in 1989. CFCs are highly reactive; for instance, a single chlorine molecule can destroy thousands of ozone molecules. The formation of ozone molecules is a slow process, and as ODS concentrations have increased, the overall ozone concentration has decreased until a new equilibrium is reached between the rate of ozone formation and degradation.

Solar radiation is a key environmental factor affecting life on Earth. It governs the functioning of terrestrial and aquatic ecosystems by controlling photobiological processes such as photosynthesis, photoperiodism, and phototropism. These processes, in turn, influence other environmental factors like temperature, humidity, and natural cycles (daily, annual, and hydric cycles), which ultimately affect organism distribution. While solar radiation is essential for life, high intensities or excessive proportions of shortwave radiation can be detrimental. High-intensity radiation and changes in spectral composition can significantly impact biological processes in organisms.

The quantity and quality of radiation reaching the Earth's surface depend on both the solar energy emitted and the atmospheric characteristics at a given location. A wide range of the electromagnetic spectrum reaches the surface, with approximately 40% being visible light or radiation. These wavelengths, ranging from 400 to 700 nm, are used by plants in photosynthesis. Another important range is the photobiological range, from 280 to 1,000 nm.

Both UVA and UVB penetrate the biosphere, but only UVB is absorbed by atmospheric ozone. Consequently, a decrease in ozone concentrations will allow more UVB to reach the Earth's surface. Of the UV radiation emitted by the sun that reaches the Earth, only 1.3% passes through the atmosphere, with 98% of this being UVA and 2% being UVB.

Animal skin physiology

In animals, the skin covers the body surface and is in direct contact with the external environment. It consists of three layers that contain additional structures such as sweat and sebaceous glands. Different species have developed supplementary forms of protection like hair, wool, and feathers, as well as keratinized tissues such as nails and hooves. The skin serves as a barrier against mechanical, physical, and chemical threats from the environment. For instance, skin thickness often increases at points regularly subjected to mechanical compression, such as hooves, paws, hands, and feet. It is also relatively impervious to microorganisms and many toxic substances.

The skin provides protection against radiation, particularly solar radiation of different wavelengths. In many animal species, the outermost layer of the skin, the epidermis, produces pigments like melanin granules that prevent radiation from penetrating deeper tissues. An example is the polar bear, whose skin has white, reflective fur and black, protective skin as an adaptation to an intense luminous environment with direct solar radiation and reflected radiation from ice and snow.

Sweat and sebaceous glands in the skin reach the surface through glandular ducts, making the skin an excretory tissue. Water excretion through sweat is a means of thermoregulation, controlling the animal's thermal conditions relative to the environment rather than maintaining the body's water balance. Cutaneous sebum, a mixture of lipids secreted by the sebaceous glands, protects the skin from moisture, providing pliability and resistance.

The skin plays a crucial role in animal growth and somatic body development as it is the primary storage and activation site of vitamin D. Vitamin D enters the organism as either D2 (ergocalciferol) or D3 (cholecalciferol), depending on its source, and reaches skin tissues via the blood. In the skin, it is stored as calciferol or a precursor and is transformed into cholecalciferol by UV rays from the sun. The cholecalciferol then returns to the circulatory system, passes through the liver, and finally reaches the kidneys, where it is converted into the vitamin D hormone (1,25-dihydroxycholecalciferol) under the influence of parathormone (PTH). This hormone acts on the intestinal mucosa by stimulating the absorption of calcium, thus preventing rickets.

Skin histology

The total cutaneous area varies among animal species; for instance, in adult humans, it is estimated to be up to 2 m^2. Different parts of the skin in various animals develop specialized structures such as hair, feathers, nails, horns, or hooves, while the presence of sweat and sebaceous glands can range from numerous to scarce or absent.

Skin thickness within a species can vary, generally being thicker on dorsal body surfaces and limb lateral surfaces, and thinner on ventral body surfaces and limb medial surfaces. These patterns can differ by species, breed, and sex. In mammals, the thinnest skin areas average from 0.4 mm in mice to 2.4 mm in Holstein dairy cows (Bos taurus), while the thickest areas average from 1.9 mm in domestic cats to 10.7 mm in male horses.

The skin is structured into three layers: the epidermis, the outermost epithelial layer; the dermis, the deeper connective tissue layer; and the hypodermis, the subcutaneous cellular tissue (see Figure 2).

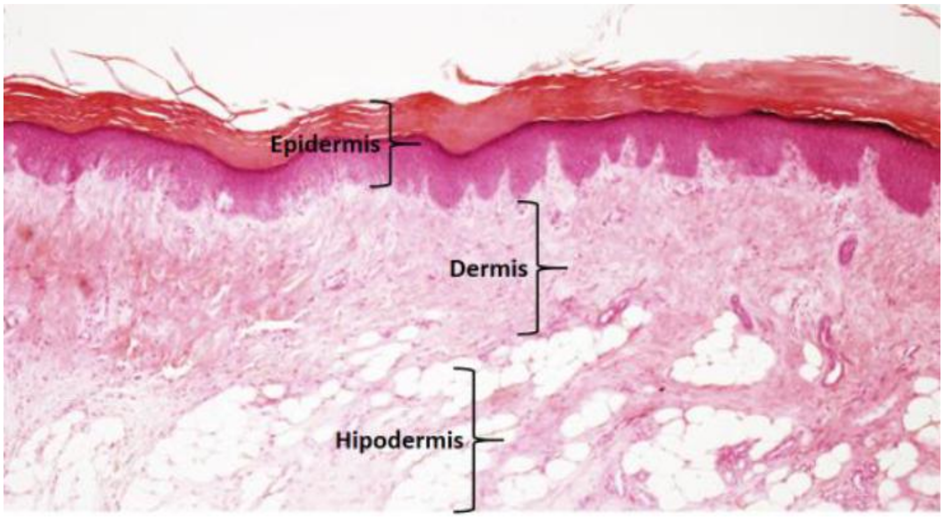

Figure 2: Layers of thick rat skin

Epidermis: The epidermis consists of keratinized, stratified layered epithelium and is typically divided into five strata: stratum germinativum, stratum spinosum, stratum granulosum, stratum lucidum, and stratum corneum.

Dermis: This connective tissue layer is divided into two regions: the papillary region, immediately beneath the epidermis, and the deeper reticular region. The papillary region is named for its numerous papillae that project into the epidermis. It is composed of a dense weave of irregular, lax fibrous connective tissue with trophic functions. The thickness of the papillary region varies widely between species, being thicker in ungulates compared to carnivores.

Hypodermis: The hypodermis is primarily composed of connective tissue that attaches the skin to bones and muscles. Its main function is to cushion external pressures and allow the skin to move freely over underlying structures. Adipose tissue is present in this layer, ranging from small clusters to large masses in the form of pads or fat deposits. In temperate climates, the hypodermis serves a thermoregulatory role by increasing in thickness during winter to retain heat. Ancillary structures such as hooves, nails, horns, and spurs originate from keratinization processes in the stratum corneum and vary in thickness and consistency.

Hair is an epidermal formation found across most mammalian species, covering the entire skin surface except for specialized areas such as paw pads, hand palms, hooves, fingernails, parts of the lips, glans, inner foreskin, vulvar labia, nipples, and limb contact surfaces. Each hair consists of a root, a stem, and a tip that protrudes from the skin. The root of a hair is surrounded by an invagination of the epidermal strata spinosum and germinativum into the dermis, reaching the papillary region and accessing blood vessels therein.

Different species exhibit varying proportions of cortical and medullary layers in their hair. For example, horses, cattle, dogs, and pigs have a thicker cortical layer compared to goats and cats. Additionally, fine, curly hair is characteristic of animals like sheep and pigs, while hedgehogs or porcupines have sharp hairs known as thorns or barbs. Hair tends to be very fine in young animals and often lacks a central medulla.

The skin exhibits evolutionary and morphophysiological adaptations to environmental conditions, which involve its morphological characteristics and its ability to regulate organism temperature in response to environmental variables. A notable example is the variation in skin thickness observed among and between different bovine breeds. Histological studies comparing Zebu cattle (Bos indicus) and Holstein breeds (Bos Taurus) have revealed that skin thickness is not uniform across the body surface within the same areas among animals of the same species but different breeds, and can also vary with age. Research examining 21 skin regions in Holstein-Friesian cattle found that skin fold measurements changed within the same area, and overall thickness increased with age.

Comparative analysis of macroscopic and microscopic skin structures in Holstein and Zebu cows demonstrated that Zebu cattle are better adapted to high temperatures. They possess shorter, thicker hair, greater overall skin thickness with a thinner epidermis and a deeper reticular dermis, and a larger number of sweat glands that are deeply implanted in the dermis. This configuration results in a greater excretory surface area and higher glandular density per unit area, enhancing heat dissipation efficiency and thus increasing tolerance to tropical temperatures. In contrast, Holstein-Friesian cattle, a dairy breed, have thinner skin with a thicker epidermis and a finer reticular dermis. The shape of their sweat glands also differs, with Holstein glands being tubular with varying degrees of torsion, while Zebu glands are more sack-like and concentrated, further optimizing heat dissipation capabilities in tropical climates.

How solar radiation affects animals

Animals exposed to prolonged solar radiation, living at high altitudes and/or in tropical regions, often lack pigment in the epidermis, have sparse hair, or experience hair loss, leading to increased susceptibility to skin diseases (references 33-36). This vulnerability arises because UV rays damage cellular DNA, causing the formation of cyclobutane pyrimidine dimers (CPD), pyrimidine (6,4) photoproducts, and pyrimidinone (6,4) photoproducts. These DNA lesions inhibit replication and transcription, increase mutations, halt the cell cycle, and can lead to cell death (reference 37). One disease associated with these factors is squamous cell carcinoma (SCC), also known as epidermoid carcinoma (references 34, 35, 36). SCC is a malignant tumor that affects keratinocytes in the epidermis, characterized by local invasiveness but not necessarily metastasis (reference 33). However, it can compromise the dermis in severe cases (reference 38).

In bovine species, SCC is most common in breeds such as Hereford, Simmental, and Holstein, all of which have unpigmented white skin, particularly around the eyes (references 34, 35). This condition, often referred to as pink eye, causes significant economic losses due to eye cancer. It has a genetic basis but is strongly associated with UV exposure, affecting older individuals more frequently, although younger animals with little facial pigmentation are also at risk (reference 39). Similar risks are observed in felids and canids (references 40, 41), but occurrences are rare in sheep and pigs (references 33, 35, 36). Certain horse breeds, including Belgian, Clydesdale, Shire, and Appaloosa, are particularly susceptible, with lesions predominantly occurring in mucocutaneous regions such as the conjunctiva, vulva, and perineum (reference 34). SCC affects approximately 20 to 30% of canids and up to 70% of felids, with no significant differences by sex, occurring most commonly in large breeds and animals over 10 years old (reference 42). In canids, lesions are commonly found on the trunk, limbs, scrotum, lips, and nail beds (reference 38), while in felids, they predominantly affect the face and ears of individuals with white fur (reference 42).

Exposure to UV light can also lead to the formation of melanocytomas, which originate from melanocytes in the epidermis—cells responsible for skin, eyelash, and hair pigmentation (reference 43). In bovines, 80 to 90% of these tumors are benign, primarily found on the extremities, and are not influenced by age or sex, being more prevalent in animals with darker colors like grey, red, and black (reference 43). Known as melanomas in other domestic animals, these tumors are typically malignant. They are common in canids and equids but rare in cats and other species (references 41, 43, 44).

In dogs, melanomas account for 4.7% of all neoplasms and over 7% of malignant tumors (references 44, 45). They most frequently occur in the mouth (56%), followed by the lips (23%), skin (11%), toes (8%), and other sites (2%), including the eyes (reference 46). Cutaneous melanomas are relatively common, but only 10% of malignant melanomas are cutaneous, predominantly affecting the head and scrotum. The incidence of melanomas in canids varies by breed, being more prevalent in breeds with distinct cutaneous pigmentation, such as the Schnauzer or Scottish Terrier (references 45, 46). Subungual melanomas are more frequent in breeds like the Irish Setter and Golden Retriever, while labial melanomas are more common in breeds such as the Irish Setter, Chihuahua, Golden Retriever, and Cocker Spaniel (references 45, 46). German Shepherds and Boxers have a higher risk of developing oral melanomas (references 47, 48). Melanomas can appear at any age between 1 and 17 years, with an average onset around 10 years, and they are more common in males than females (reference 47).

Melanoma is rare in cats, accounting for less than 1% of oral neoplasms and approximately 0.5% of cutaneous neoplasms (references 49, 50, 51). Ocular and cutaneous melanomas are more common than intraoral ones (references 52, 53). On the skin, melanomas most frequently occur on the head, tail, distal extremities, and lumbar area (references 46, 53, 54). Prognosis for melanoma in cats is often poor, with about half of cases experiencing recurrence and regional metastases (references 46, 54, 55). Affected cats typically range in age from 2 to 18 years, with a peak incidence between 8 and 12 years, and there is no significant impact of sex or breed on frequency (references 54, 55).

Another UV-related condition is the development of hemangiosarcomas, malignant tumors most commonly found in middle-aged and elderly dogs, particularly large breeds like the greyhound.

These tumors typically affect the spleen, right atrium of the heart, subcutaneous and dermal tissues, and occasionally the liver (reference 56). Hemangiomas, benign neoplasms in skin capillaries of the trunk, limbs, and soft tissues, are also associated with UV exposure and often serve as precursors to hemangiosarcomas (reference 57).

Pathological effects of ultraviolet radiation

UVA radiation is capable of inducing erythema, immediate or delayed pigmentation changes, alterations in dermal connective tissue, release of vasoactive mediators, and oxidative stress due to photo-oxidation (reference 58). It can also worsen UVB-induced erythema, contribute to carcinogenesis and elastosis, and cause structural changes in DNA and elastic fibers (reference 58).

Exposure to UVA is implicated in various drug-induced photosensitivity reactions and is a significant factor in diseases such as polymorphic light eruption, chronic actinic dermatitis, actinic reticuloid, lupus erythematosus, solar urticaria, persistent light reaction, and xeroderma pigmentosum (XP) (references 59, 60). Both experimental studies and clinical evidence strongly link prolonged UV light exposure to skin cancer, particularly malignant melanoma (MM), squamous cell carcinoma (SCC), and basal cell carcinoma (BCC) (references 59, 60).

Photosensitivity in animals is classified into three main types. Type I, or primary photosensitivity, occurs when fluorescent compounds such as hypericin, fagopyrin, or phenothiazine (sulfoxide phenothiazine) are ingested and deposited undisturbed on the skin due to the liver's inability to process and excrete them normally. Type II, known as abnormal synthesis of endogenous pigment or congenital porphyria, results from the accumulation of endogenous pigments like uroporphyrin I, coproporphyrin I, and protoporphyrin III in the blood and tissues, stemming from abnormalities in heme group biosynthesis enzymes. For instance, bovines with congenital protoporphyria lack uroporphyrinogen III cosynthetase, essential for heme biosynthesis. Type III, or hepatotoxic photosensitivity, is more prevalent and economically significant. It occurs when phylloerythrin, a product of chlorophyll digestion normally excreted in bile, accumulates in the circulatory system due to liver dysfunction caused by various plant, fungal, or chemical toxins. These toxins inflame liver cells and bile ducts, obstructing bile flow and leading to jaundice or yellow discoloration.

Beneficial effects of ultraviolet radiation

Solar radiation provides several critical benefits to animals. Firstly, it helps homeothermic animals regulate their internal body temperature, crucial for maintaining metabolism (62). Additionally, UVB radiation plays a significant role in vitamin D metabolism, essential for preventing deficiencies that can lead to skeletal issues such as increased fracture risk. Vitamin D3, synthesized with UVB exposure, regulates the absorption, transport, and deposition of calcium and phosphorus, vital for bone maintenance and growth, as well as hormonal functioning, organ development, and embryogenesis (62). Without adequate UVB radiation, animals may struggle to incorporate essential nutrients properly, even with an optimal diet and temperature (62).

Moreover, irradiation plays a crucial role in food safety by preserving food, preventing degradation, spoilage, and the emergence of undesirable conditions like sprouting in tubers. It also serves to eliminate certain insects, fungi, and bacteria, contributing to overall food quality and safety (63).

CONCLUSIONS

Domestic animals are routinely exposed to ultraviolet radiation, but shifts in climate patterns could heighten their exposure to UVB radiation, potentially leading to adverse health effects. Sensitivity to such exposure varies among species and even between different breeds within the same species.

Many animals may develop skin conditions and even skin cancer, resulting in substantial economic losses in agriculture, compromising animal health and welfare, and affecting the quality and safety of animal products destined for human consumption.

LITERATURE CITED:

1. Toca TC. Impacto ambiental empresarial y fallas de la acción pública: una realidad de las localidades bogotanas. Argos 2011;28:244-269.
2. Albanil E, Ramírez R, Jiménez B. Reporte del Clima en México http://smn.cna.gob.mx/climatologia/analisis/reporte/ Anual2014.pdf, Consultado 26 de Feb, 2015.
3. Alonso S, Ramírez N, Taylor PJ. El cambio climático y su impacto en la producción de alimentos de origen animal. http://www.veterinaria.org/revistas/redvet/ n111112.html, Consultado 29 de May, 2015.
4. Ferramola SA, Sancovich HA. Interacciones de las radiaciones electromagnéticas y especies reactivas del oxígeno sobre la piel. Rev Argent Dermatol 2006;87:113-120.
5. Rivas AM, Rojas EE, Cortés NJ, Santander GE. Efecto de la altura en la radiación solar ultravioleta en Arica Norte de Chile. Revista Facultad de Ingeniería, U.T.A. 2002;10:59-62.
6. Bohórquez BJ, Pérez JF. Radiación ultravioleta. Ciencia & Tecnología para la salud visual y ocular. Rev Lasalle 2007;9:97-104.
7. Navas G, Jairo T, Rodrigo C. Non-Ionizing Radiation Detection. Dyna 2009;76:71- 81.
8. Guerreo AJ, Peréz AJ. Las radiaciones no ionizantes y su efecto sobre la salud humana. Rev Cubana Med Milit 2006;35:3-11.
9. Pérez A, Miranda LR. Radiaciones electromagnéticas y salud en la investigación médica. Rev Cubana Med Militar 2010;39:35-43.
10. Mignone C, Barnes R. More than meets the eye: the exotic, high-energy Universe. Sci in School 2012;24:53-58.
11. Rivas A, Rojas E, Madronich S. Aumento del índice solar ultravioleta con la altura. Rev Chilena Ing 2008;16:383-388.
12. Gonzáles PM, Vernhes TM, Sánchez LA. La radiación ultravioleta. Su efecto dañino y consecuencias para la salud humana. Theoria 2009;18:69-80.
13. Vallejo EO, Vargas N, Martínez LM, Agudelo CA, Ortiz IC. Perspectiva genética de los rayos UV y las nuevas alternativas de protección solar. http://www.scielo. org.ar/scielo.php?script=sci_arttext&pid=S1851300X2013000300002Rev, Consultado 17 Sep, 2015.
14. Luigi PG, Rightler AL, Heronc M, Gabbuttc CD. Extending human perception of electromagneticradiation to the UV region through biologically inspired photochromic fuzzy logic (BIPFUL) systems. Chem Commun 2016;52:1474-1477.
15. Byrne SN, Hammond KJ, Chan CY, Rogers LJ, Beaugie C, Rana S, Marsh- Wakefield F, Thurman JM, Halliday GM. The alternative complement component factor B regulates UV-induced oedema, systemic suppression of contact and delayed hypersensitivity, and mast cell infiltration into the skin. Photochem Photobiol Sci 2015;14:801-806.
16. Sánchez C. Consideraciones sobre la capa de ozono y su relación con el cáncer de piel. Rev Méd Chile 2006;134:1185-1190.
17. Erickson DJ, Sulzberger B, Zeppc RG, Austind AT. Effects of stratospheric ozone depletion, solar UV radiation, and climate change on biogeochemical cycling: interactions and feedbacks. Photochem Photobiol 2015;14:127-148.
18. Environment Canada. The UV Index and Ozone http://www.ec.gc.ca/uv/ Default.asp?lang=En&n=C74058DD, Accessed Feb 16, 2015.

19. Bornman JF, Barnes PW, Robinson SA, Ballaré CL, Flinte SD, Caldwell MM. Solar ultraviolet radiation and ozone depletion driven climate change: effects on terrestrial ecosystems. Photochem Photobiol 2015;14:88-10.
20. Baiz AF, McKenzie RL, Bernhard G, Aucamp PJ, Ilyas M, Madronich S, Tourpali
21. K. Ozone depletion and climate change: impacts on UV radiation Photochem Photobiol. Sci 2015;14:19-52.
22. Carrasco RL. Efecto de la radiación ultravioleta–B en plantas. IDESIA Chile 2009;3:59-76.
23. Castellanos I, Clarena G, Rodríguez T, Iregui G. Estructura histológica normal de la piel del perro. Rev Med Vet 2005;10:104-122.
24. Vega PC. Manual de Histología Esquemática. 1ra ed. La Habana, Cuba: Editorial Pueblo y Educación; 1980.
25. Dellmann HDB. Histología veterinaria. 2a ed. España: Editorial Acribia, Zaragoza; 1994.
26. Megías M, Molist P, Pombal MA. Atlas de histología vegetal y animal. Órganos animales tegumento, https://mmegias.webs.uvigo.es/descargas/o-ategumento.pdf, Consultado 24 Feb, 2016.
27. Paniagua R, Nistal M, Sesma P, Álvarez U, Fraile M, Anadón B, Sáez RFS, De Miguel MP. Citología e histología vegetal y animal. 2a ed. España: Editorial McGraw- Hill-Interamericana de España; 1997.
28. Ross MH, Pawlina W. Histología Texto y Atlas. 7ª ed. Barcelona, España: Editorial Wolters Kluwer; 2016.
29. Esquivel VC. La raza, el pelo y la piel en función del bienestar animal. Mundo Pecuario 2012;1:73-85.
30. Suro RJ, Gutiérrez FL, Ruiz AJ, Bouhann P. El pelo. Generalidades y funciones. Dermatología CMQ 2007;4:218-223.
31. William J. Applied Veterinary. 2a ed. USA: Editorial Mosby; 1993.
32. Kamwanja LA, Chase CC, Gutierrez JA, Guerriero V, Olson TA, StatusHammond AC, Hansen PJ. Responses of bovine lymphocytes to heat shock as modified by breed and antioxidan. J Anim Sci 1994;72:438-444.
33. Pérez EH. Fisiología Animal II. http://cenida.una.edu.ni/relectronicos/RENL 50P438.pdf. Consultado 28 Sep, 2016.
34. Rosolem MC, Moroz LR, Rodigheri SM. Carcinoma de células escamosas. Pubvet 2012;6:6-14.
35. Ramos AT, Mollerke ND, Elias FM, Gevehr FC. Carcinoma de células escamosas em bovinos, ovinos e eqüinos: estudo de 50 casos no sul do Rio Grande do Sul. Braz Vet Res Anim Sci 2007;44:5-13.
36. Fabricio KL, Dantas AF, Riet CF, De Miranda NE, Simões SV, Azevedo SS. Fatores de risco associados à ocorrência de carcinoma de células escamosas em ruminantes e equinos no semiárido da Paraíba. Pesq Vet Bras 2012;32:881-886.
37. Targino J, Almeida S, Macedo E, Almeida BE, Santana de OR, Anjos FE, Ocampos PPM. Squamous cell carcinoma in the frontal region of the head in a goat. Acta Scient Vet 2013 41:4-8.
38. Tafurt Y, Marin MA. Principales mecanismos de reparación de daños en la molécula de ADN. Rev Biosalud 2014;132: 95-110.
39. Costa C, Ramos VD, Huppes R, Bardoza DA, Gaspar RA, Rivera CL, Ramirez UR. Cryosurgery in the treatment of squamous cell carcinoma in dog. Rev Colomb Cienc Anim 2013;5:213-221.
40. Heather ST. Combata el cáncer de ojo. Hereford, Bs.As. 1999;(64):38-40.
41. Olinda RG, Frade MT, Soares GS, Aguiar GM, De Costa VM, Lucena RB, De Dantas AF. Bovine demodicosis associated with squamous cell carcinoma of the vulva. Acta Scient Vet 2013;41:29-32.
42. Mukaratirwaa S, Chipunzaa J, Chitangaa S, Chimonyoa M, Bhebhea E. Canine cutaneous neoplasms: prevalence and influence of age, sex and site on the presence and potential malignancy of cutaneous neoplasms in dogs from Zimbabwe. J S Afr Vet Ass 2005;76:59–62.
43. Revista de la Asociación Madrileña de Veterinarios de Animales de Compañía.

https://es.scribd.com/document/26893256/Revista-de-La-Asociacion-Madrilena-de- Veterinarios, Consultada 14 Ene, 2010.

44. Chávez VC, Astaiza MJ, Benavides MC, Vallejo TD. Tumor maligno derivado de melanocitos en piel de un bovino de presentación inusual: estudio de caso. Rev Med Vet 2015;29:63-72.
45. Iakatos I, Mirela E, Cadar, Ali B. Cutaneous tumors' incidence in dog. Lucrări Stiinłifice Medicină Veterinară 2009;13:475-381.
46. Silva HG, Juárez BF, López VM, Dávila PM. Squamous cell carcinoma in dogs from Culiacan, Sinaloa, Mexico Retrospective Rev (2006-2014). Rev Cient, FCV-LUZ 2015;25:573-584.
47. Goldschmidt MH, Shofer FS. Skin tumors of the dog and cat. Oxford, UK: Butterworth Heinemann; 1992;2:142-151.
48. Todoroff RJ, Brodey RS. Oral and pharyngeal neoplasia in the dog: a retrospective survey of 361 cases. J Am Vet Med Assoc 1979;175:567-571.
49. Oakes MG, Lewis DD, Hedlund CS, Hosgood G. Canine oral neoplasia. Contin Educ Pract Vet Comp 1993;15:15-30.
50. Patnaik AK, Mooney S. Feline melanoma: a comparative study of ocular, oral and dermal neoplasms. Vet Pathol 1988;25:105-112.
51. Stebbins KE, Morse CC, Goldschmidt MH. Feline oral neoplasia: a ten-year survey. Vet Pathol 1989;26:121-128.
52. Miller WH, Scott DW, Anderson WI. Feline cutaneous melanocytic neoplasms: a retrospective analysis of 43 cases (1979-1991). Vet Dermatol 1993;4:19-26.
53. Engle CG, Brodey RS. A retrospective study of 395 feline neoplasms. J AM Anim Hosp Assoc 1969;5:21-31.
54. Day MJ, Lucke VM. Melanocytic neoplasia in the cat. J Small Anim Pract 1995;36:207-213.
55. Van Der- Linde SJS, De- Wit MML, Van- Garderen E, Molenbeek RF, Van Der- Velde ZD, De- Weger RA. Cutaneous malignant melanomas in 57 cats: identification of (amelanotic) signet-ring and balloon cell types and verification of their origin by immunohistochemistry, electron microscopy, and in situ hybridization. Vet Pathol 1997;34:31-38.
56. Luna LD, Higginbottham ML, Henry CJ, Turnquist SE. Feline non-ocular melanoma: a retrospective study of 23 cases (1991-1999). J Feline Med Surg 2000; 2:173- 181.
57. Weinborn AR, Issotta CC, Agurto MM, Lara LJ. Descripción clínica de hemangiosarcoma (HSA) cutáneo metastásico en un canino galgo: estudio clínico de un caso. Rev Med Vet 2015;2:107-116.
58. Aita N. Hemangioma of the ileum in a dog. J Vet Med Sci 2010;72:1071-1073.
59. López CC, Aréchiga OE, López CM. Protein kinases and transcription factors activation in response to UV-radiation of skin: Implications for carcinogenesis. Int J Mol Cienc 2012;13:142-172.
60. Duro ME, Campillos P, Causín S. El sol y los filtros solares. Medifam 2003;13: 159- 165.
61. Alvarez FE. Consecuencias del estrés oxidativo de la piel por radiaciones ultravioleta. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864030019950001 00004, Consultado 10 Nov, 2016.
62. Cruz CF. Fotosensibilización. http://www.ammveb.net/clinica/fotosensibilizacion. pdf, Consultado 20 Oct, 2016.
63. Fernández L, Poletta GL, Imhof A, Siroski PA. Efectos de la radiación ultravioleta natural y artificial (UVA/ UVB) sobre la concentración plasmática de calcio y fósforo y el crecimiento en crías de Caiman latirostris. InVet 2013;15:75-82.
64. Ross LI, Watson D, Escandarani S, Miranda A, Troncoso A. La radiación a la mesa. Rev Chilena Infect 2009;26:318-330.