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Research Article

Dietary Portfolios for the Healing of Pressure Ulcers

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Abstract

Introduction: Pressure ulcers (PUs) represent a localized injury to the skin and underlying tissues provoked by prolonged pressure, friction, or shear. The progression of PUs is highly affected by nutritional status, as malnutrition, obesity, and deficiencies in key nutrients impact collagen synthesis, angiogenesis, and immune responses. Dietary portfolios (DiPos), combines functional foods rich in bioactive compounds, have become a potential nutrigenomic alternative to modulate inflammation and improve wound healing, although their application in PUs remains under-explored.

Objective: Analyze the possible contribution of bioactive compounds in a proposed anti-inflammatory dietary portfolio composed of quinoa, pumpkin seeds, chia, and sesame seeds, and describe their potential impact on inflammatory modulation and pressure ulcer healing.

Methods: A narrative review was conducted using original research articles, theses, case reports, and systematic reviews published between 2012 and 2025. Searches were performed in PubMed, Elsevier, and SciELO, using terms related to pressure ulcers, healing, nutrition, inflammation, polyunsaturated fatty acids, and epithelialization. Sixty-two full-text documents that met the relevance criteria were included.

Results: Evidence shows that pressure ulcer healing involves orchestrated inflammatory, proliferative, and remodeling phases, all of which are dependent on adequate nutrient availability. The functional foods analyzed provide bioactive compounds that can positively influence these processes. Quinoa offers flavonoids and minerals that promote antioxidant activity and favor the polarization of macrophages toward an anti-inflammatory profile. Pumpkin seeds provide tocopherols and tocotrienols with antioxidant and anti-inflammatory properties. Chia seeds supply omega-3 fatty acids, arginine, and proline, which promote collagen synthesis and modulate inflammatory mediators. Sesame seeds provide unsaturated fatty acids and antioxidant enzymes such as GPx and CAT, which reduce oxidative stress and inhibit inflammatory pathways, including NF-κB and MAPK.

Conclusion: Integrating functional foods into a specific DiPo may represent a promising complementary strategy for the treatment of pressure ulcers. By reducing inflammatory mediators, regulating oxidative stress, and improving tissue repair, DiPos could shorten healing times and decrease complications such as infections. Further clinical trials are needed to validate their therapeutic application.

Keywords: *Dietary Portfolios; Pressure Ulcers; Dietary Supplements; Bioactive Compounds and Inflammation*

Abbreviations

ALA: α-Linolenic Acid; AHA: American Heart Association; CAT: Catalase; DiPos: Dietary Portfolios; DHA: Docosahexaenoic Acid; EPA: Eicosapentaenoic Acid; FAO: Food and Agriculture Organization of the United Nations; GPx: Glutathione Peroxidase; IL-6: Interleukin-6; IL-1β: Interleukin-1β; LA: Linoleic Acid; MAPK: Mitogen-Activated Protein Kinase; NF-κB: Nuclear Factor Kappa-Light; NCEP: National Cholesterol Education Program; ONS: Oral Nutritional Supplements; Pus: Pressure Ulcers; PUFAs: Polyunsaturated Fatty Acids; TNF- α: (TNF-α)

Introduction

Pressure ulcers (PUs) are injuries or sores that are produced by friction or shearing and generate tissue loss where they focus. Usually, PUs appears due to constant pressure applied by the body weight of individuals on a bony prominence and the surrounding tissues against an external surface during a prolonged time period [1], resulting in a series of ischemic processes due to a reduction in capillary flow in the skin covering the bony prominences and underlying tissues and a lack of oxygen, which can trigger the onset of necrosis [2].

People with PUs generally suffer both physical and emotional pain, stress, discomfort, and social rejection by those who care for them due to the unpleasant odor that can develop, with the healing period being a major factor that exacerbates these conditions [3]. Several public health issues, including malnutrition and obesity, can impact the progression of PUs. Malnutrition leads to a limited intake of nutrients as well as energy, which are required for tissue repair; whereas obesity leads to a decrease in circulation through blood vessels, which means that nutrients do not efficiently reach the affected area, causing alterations in healing or repair time. Likewise, people with obesity have an increased risk of infection [4].

The use of dietary portfolios (DiPos) has been demonstrated as a nutrigenomics tool with significant health benefits. These portfolios consist of a combination of functional foods selected for their chemical composition or bioactive compound content. Their role has been described mainly in infectious diseases [5] and chronic degenerative diseases [6,7], focusing on their effect on the lipid profile. Moreover, some bioactive compounds with this function often have anti-inflammatory properties, but this has not been fully clarified [8].

Aim of the Study

This study aims to describe the possible participation of certain bioactive compounds contained in a DiPo that might possess anti-inflammatory effects on the natural evolution of PUs and potential beneficial healing effects for patients suffering from the disease.

Materials and Methods

We conducted an information search considering original scientific articles, theses, clinical cases, and systematic reviews, using keywords such as: sores / healing / ulcers / nutrition / inflammation / skin repair / polyunsaturated fatty acids / epithelialization. The information was compiled from PubMed, Elsevier, and SciELO meta-databases, spanning the period from 2012 to 2025, due to the lack of focus or current relevance on the use of dietary portfolios as a treatment option for PUs. Finally, a total of 52 articles were selected from that period, most of which were available in full text.

Results and Discussion

Pressure ulcers (PUs)

PUs are described as injuries caused to the skin by long-term pressure. This type of injury appears when bone protrusions are regularly faced with another hard surface (bed, chair, etc.). This pressure exerted on the skin induces an ischemic effect, which leads to different stages of ulceration [9]. Every patient susceptible to developing PUs should be assessed with appropriate instruments. In a hospital setting, the most widely used diagnostic tools for this assessment are the Braden and Norton scales, whose main objective is to detect the risk of development and initiate preventive measures [10].

Once normal capillary pressure (6-32 mmHg) increases, an ischemic process begins, unleashing a series of inflammatory processes that manifest as skin erythema. When the pressure remains, it can generate necrosis and ulceration [11]. Commonly, ulcers can be caused by three forces: the first one is the previously mentioned pressure between two planes (the bone protrusions of the patient and an external plane), which, if pressure exceeds 32 mmHg for an extended period of time, can cause ischemic lesions, followed by tissue hypoxia and eventually necrosis. Other common forces present in hospitalization is the friction induced by continuous or repetitive rubbing, leading to a rise in local temperature, blistering, and damage to the epidermis. The third most common force in clinical practice is shearing, a force that combines pressure and friction, where, in addition to pressure being exerted on a bony protrusion, there is an added sliding motion, such as in the Fowler position, particularly in patients with trauma or respiratory complications, where the body slides, resulting in pressure and friction on the sacrum. In these situations, disruption of the blood supply tends to manifest earlier.

Etiology and assessment of pressure ulcers

PUs are classified into stages according to the intensity or degree of skin involvement (Figure 1). The most susceptible areas for the development of PUs in medical practice are the nose (prolonged exposure to oxygen masks), lips and tongue (inappropriate or prolonged use of endotracheal tubes), mid-pelvic region and soft tissue areas (caused by folds in bed sheets), and wrists and elbows (in people with mechanical restraints) [12]. PUs generates primary complications, including local necrosis, which affects joints and leads to fistulas and hemorrhages. A sign of infection is considered a sign of infection when the PUs are at stages III and IV and when there is redness of the skin or suppuration of the wound [10].

After PUs develop, the number and position, as well as the stage and features present, should be carefully considered. A constant and periodical assessment must be managed in those patients who are known to have a prolonged hospital stay, and it is highly suggested to carry out an initial assessment at least 8 hours after admission to detect patients at risk of developing PUs, particularly in older adults, who are more susceptible to PUs development. Lesions usually appear in the first 24 hours of hospitalization and, although prevalent, most are avoidable [2].

There are intrinsic factors associated with the appearance of PUs, such as physical condition (immobility), age, malnutrition, obesity, anemia, circulatory disorders, diabetes, heart failure, septicemia, or certain skin disorders (edema, dry skin, lack of elasticity). On the other hand, external factors in the hospital, such as absence or improper use of preventive equipment, poor technique or limited knowledge about wound healing management, wetness (incontinence, profuse sweating, wound exudate), support surfaces, fixations, splints, or drug treatments (immunosuppressants, sedatives, vasoconstrictors) [13].

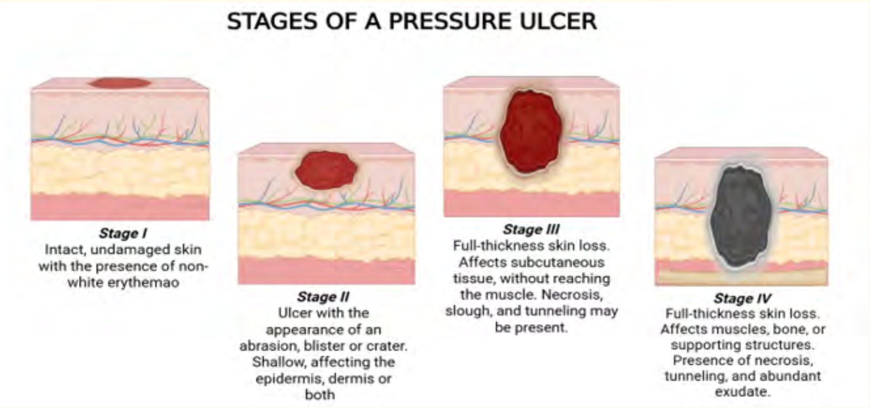

Figure 1: *Visual representation of the stages of PUs. Depending on the stage of the PUs, the damage to the skin layers will be more or less involved. Stage I shows minor damage where there is still no loss of skin continuity. In stage IV, all skin layers are compromised and necrosis appears.*

Healing

The healing process depends on the hemostasis of each person. Overall, it has been suggested that the healing process consists of three phases: the first one is the inflammatory phase. After the formation of a fibrin clot, macrophages and neutrophils migrate towards the injured tissue and are responsible for endogenous debridement. In this process, M1 macrophages, which have phagocytic activity in the production of proinflammatory mediators, and M2 macrophages, with anti-inflammatory activities that stimulate neovascularization, stromal remodeling (connective tissue that provides structure and support to the organs and tissues in the body), tissue repair, and fibroblast proliferation [14]. The second phase, known as the proliferative phase, is defined by the generation of collagen III (which, unlike collagen I and II, produces thinner fibers, giving tissues greater elasticity) by fibroblasts, promoting angiogenesis, re-epithelialization (migration and proliferation of epidermal keratinocytes), as well as wound contraction. Finally, the third phase, known as remodeling, involves a rearrangement of fibers, replacing collagen III with collagen I, which is stronger and gives the tissue greater tensile strength, resulting in skin restoration. This healing process culminates in fibrinolysis. These phases of healing occur optimally when the patient is in an optimal nutritional state, which will allow the wound to receive all the necessary nutrients for proper healing [15].

Role of nutrition in healing

Nutrition plays a fundamental role in the healing of injuries and tissue repair [15]. Studies have shown that malnourished patients have a higher incidence of developing PUs despite factors such as age and comorbidities [16]. This is because cell proliferation and protein synthesis, both processes which occur during healing, increase calories and protein requirements [17]. Nevertheless, with a decreased intake of energy, protein, and antioxidants, the incidence of chronic wound delay is more frequent, the inflammatory phase is prolonged, and fibroblast production, collagen formation, and angiogenesis are reduced [18]. The nutritional treatment considered for managing pressure ulcers focuses on providing the following recommendations (Table 1), according to their effects on the lesions [19-21].

Nutrient	Recommendation	Effects on Pressure Ulcers (PU)
Energy	30-35 kcal/kg/day	For adult patients at risk of malnutrition or with existing malnutrition. Metabolism increased because of cell proliferation, protein synthesis, and production of biochemical mediators involved in wound healing which require energy (Inflammatory phase)
Protein	1.2-1.5 g/kg (Stage I/II) 1.5-2.0 g/kg (Stage III/IV)	For adult patients at risk of malnutrition or with malnutrition to support wound healing. necessary for cell proliferation, production of granulation tissue, and growth factors (Inflammatory phase). Increased requirement because of collagen deposition (Proliferative phase).
Increased Energy Density	Oral nutritional supplements (ONS) / fortified foods	Increase caloric and protein intake to meet nutritional requirements. Consider high-protein, high-calorie, zinc- and antioxidant-enriched ONS (for Stage II or higher).
Fluids	30 ml/kg/day or 1 ml/kcal/day	Adequate fluid intake is required to support blood flow to injured tissues and prevent further skin breakdown.
Multivitamins	Individualize	Vitamin and mineral supplementation should only be considered when nutrient deficiencies are suspected or confirmed.
Amino Acids	Arginine Glutamine (0.57 g/kg body weight)	Arginine is not recommended for critically ill patients

Vitamin A	10,000-50,000 IU/day (severe malnutrition), oral	Provide for 10 to 14 days to stimulate epithelialization, collagen formation, and immune response. Monitor for adverse effects such as mucosal dryness, vomiting, headache, hepatic damage, alopecia, bleeding, and renal failure.
Vitamin C	100-200 mg/day (Stage I/II) 1000-2000 mg/day (Stage III/IV). Avoid doses >2000 mg/day	Promotes collagen synthesis. Disposes bacteria, an antioxidant that helps wounds transform from the inflammatory to the proliferative stage (Inflammatory phase).
Zinc	40 mg/day (elemental zinc)	An antioxidant mineral that supports cellular proliferation, growth, and protein synthesis. Inadequate supply can affect B- and T-lymphocyte production, but excess intake can delay healing (Inflammatory phase).
Nutrition Education	None apply	Inform patients about malnutrition risk, consequences, improvements in dietary intake and nutritional status; establish regular meals and timing for ONS administration.

Table 1: *Components of nutritional treatment in pressure ulcers.*

Several bioactive compounds have been reported to play an important role in wound healing, including arginine, which is involved in the synthesis of proline, a precursor of collagen that is essential in the healing process. In addition, arginine is a precursor of endothelium-derived relaxing factor, which has a vasodilator effect, increasing oxygenation to wounds [22]. Vitamin C, for its part, contributes to angiogenesis and collagen synthesis and maturation, promoting iron absorption and acting as an immunostimulant [23]. Vitamin D plays a fundamental role in the skin regeneration process as well as in the formation of angiogenesis. Vitamin A has been described as an element which promotes the proliferation of macrophages in the affected area [15], in addition, zinc promotes tissue regeneration and recovery.

In recent years, an emerging research area in the field of molecular nutrition is nutrigenomics and the development of dietary portfolios (DiPos). DiPos are based on the synergistic effect of different food compounds to regulate biochemical parameters related to certain diseases. Among the foods most used in the development of DiPos are oats, nopal, chia, and soy. However, these are not the only foods used in the design of DiPos. The use of certain seeds (Table 2) could be a new proposal that could contribute to the creation of specialized diets for different conditions and to the consumption of functional foods, due to their biochemical composition and bioactive compound content [24].

Food	Nutritional relevance	Reference
Quinoa Seed	Quinoa seeds possess an important amino acid content that is beneficial for human health. According to the FAO, a sufficient serving of quinoa can provide more than 150% of the daily requirements of essential amino acids in schoolchildren and more than 200% in adults. Its seeds contain significant amounts of bioactive compounds that can modify cell function by reducing oxidative stress, thanks to their anti-inflammatory and immunomodulatory properties.	[34-36]
Pumpkin seed	Pumpkin seeds are notable for their protein content, as well as their anti-inflammatory and antimicrobial properties and for their presence of amino acids such as arginine (essential for healing). They are also an excellent source of zinc, which strengthens the immune system. They contribute to wound healing by promoting collagen synthesis and inflammatory response.	[37,38]

Chia seed	Chia seeds contain significant concentrations of arginine and proline, which stimulate collagen synthesis. The nutrients in chia seeds promote collagen production and prevent inflammation. Arginine reduces nitrogen loss by activating T lymphocytes (which activate the formation of macrophages and fibroblasts): at the skin level, they are involved in collagen synthesis, promoting healing, and aid in cell replication, immune response, and blood circulation. Also important for its vitamin A content, which helps regulate the proliferation of dermal fibroblasts and epidermal keratinocytes. This seed is rich in α-linolenic acid (ALA, ω-3) and linoleic acid (LA, ω-6).	[39,40]
Sesame seed	The consumption of 3 spoonfuls of sesame seeds can provide iron (an essential component of hemoglobin for transporting oxygen), copper, and vitamin B6, the latter two of which help produce hemoglobin. Taken together, they promote hematopoiesis, the basic process for angiogenesis, which is essential for hemostasis and the response to injuries and infections. It has antioxidant properties that protect tissues from oxidative damage when an injury occurs.	[41,42]

Table 2: *Health properties of certain seeds.*

Dietary portfolio

DiPos consists of a combination of two or more foods that are functional and/or have been described as having significant biological activity in different studies, mainly in order to prove the effects on physiological or metabolic processes with positive implications for health. Specific portfolios have been established, such as the combination of functional foods facilitating a reduction in metabolic syndrome components, with hypolipidemic, hypoglycemic, anti-inflammatory, antioxidant, and prebiotic effects [25]. Interestingly, the American Heart Association (AHA) and the National Cholesterol Education Program (NCEP) both recommend the use of dietary portfolios to control lipid concentration. However, it is important to note the favorable results in studies related to obesity and insulin resistance, metabolic syndrome, and even in patients with lipodystrophy, where the ability of DiPos to regulate the lipid profile and glucose levels has been pointed out [26]. The use of DiPos has even been proposed in patients with lipodystrophy to reduce factors associated with cardiovascular risk, such as oxidative stress and inflammation [27].

Lipid mediators of inflammation

Polyunsaturated fatty acids (PUFAs) are recognized essential fatty acids that have a significant impact on the healing process, as they can modulate cell migration and proliferation, phagocytic capacity, and the production of inflammatory mediators [28]. PUFAs influence the synthesis of proinflammatory substances and can be classified into two main types: α-linolenic acid (ALA, ω-3) and linoleic acid (LA, ω-6). ω-6 is currently the most consumed in the diet, and its intake is associated with enhanced skin hydration and elasticity, which prevents the formation of PUs in hospitalized patients [28]. This is due to their mechanical properties of modulating cellular response, increasing the migration and functions of inflammatory and endothelial cells, as well as inducing angiogenesis. On the other hand, omega-3s such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) have been described as antioxidant elements that can help protect and hydrate the skin, repair the skin's barrier function, and act as precursors to resolvins, improving anti-inflammatory processes [29]. These effects have been described in oral and topical treatments [30]. A possible explanation for this effect on the skin is related to the ceramide profile in the skin [31], although this process has not been fully explored.

Arachidonic acid is the second most abundant fatty acid in injured tissue after tissue damage. When it is metabolized, it produces eicosanoids that play a role in mechanisms related to skin integrity, such as modulating inflammatory responses and maintaining the balance of oxidation-reduction processes [32]. Arachidonic acid and its metabolites have been shown to promote wound healing by inducing cell migration and angiogenesis [33].

Antiinflammatory DiPo for PUs

One of the foods proposed in this DiPo is quinoa seed (Chenopodium quinoa), which is found in the Andean region of South America. It plays an essential role in the inflammatory phase and has been reported to improve the immune system related to its high concentration of zinc, iron, and B vitamins. Quinoa has been described as a food rich in antioxidants such as flavonoids, quercetin, and kaempferol, compounds with anti-inflammatory properties, reducing oxidative stress and the risk of chronic diseases [44]. In addition, it is a food rich in saponins, which have been proposed to enhance anti-inflammatory potential by suppressing the release of pro-inflammatory cytokines, including tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6) in cell lines [45].

Another seed that has been extensively studied for its antioxidant properties is pumpkin seed, which is rich in tocopherols, specifically γ-tocopherol, followed by α- and δ-tocopherols, as well as α-tocotrienol, β- and γ-tocotrienols, which have been described as assisting in reducing oxidative stress [46,47], and inflammation by neutralizing free radicals and modulating some inflammatory pathways [37]. Another seed that has been of scientific interest in recent years is chia, native to Mexico and Central America. It contains vitamins such as vitamin C, which contributes to collagen formation; vitamin E, which has antioxidant action; and vitamin A, which acts as an anti-inflammatory and promotes rapid wound healing. It also contains a wide variety of amino acids such as glutamic acid, arginine, leucine, valine, serine, and phenylalanine, among others. These amino acids contribute to the formation of tissues, enzymes, antibodies, and hormones. Glutamic acid and arginine can stimulate collagen synthesis, promoting healing. Arginine acts by reducing nitrogen loss through its effect on T lymphocytes, which activate the formation of macrophages and fibroblasts that intervene in collagen synthesis, promoting healing [37,48].

Finally, sesame seeds (*Sesamum indicum* L.) are a food with a higher protein content than seeds such as rice or wheat [41]. It also stands out for its high content of unsaturated fatty acids, such as oleic and linoleic acids, with lower amounts of saturated fatty acids, such as palmitic and stearic acids, in addition to its fiber content. One of its main properties has been reported to be related to antioxidant enzymes such as glutathione peroxidase (GPx) [49] and catalase (CAT), which degrade peroxides (compounds with an oxygen-oxygen bond), suggesting that the latter reduces hypoxia in skin wounds [50]. It can also decrease the activity of the proinflammatory cytokines IL-1β (interleukin-1β) and TNF-α, in addition to inhibiting the NF-κB (nuclear factor kappa-light chain-enhancing factor of activated B cells) and ERK/p38 MAPK (mitogen-activated protein kinases) pathways, which are crucial in inflammatory processes [41,51,52].

Conclusion

Despite the recommendations in clinical practice focused on the diet and nutrition of patients with PUs, both for prevention and treatment, the use of PoDis could be an emerging tool that could reduce the recruitment of proinflammatory markers in the lesion area and regulate the oxidative stress that is triggered, with a much shorter response time in healing and improving the immune response in patients, reducing the risk of sepsis and hospital infection. Dietary portfolios not only constitute a dietary monitoring tool, but also serve as a strategic component to improve clinical outcomes and the quality of life of individuals with pressure ulcers.

Conflict of Interest

The authors declare no conflict of interest.

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