



FROM GENES TO SOCIETY

MULTIDISCIPLINARY STUDIES ON SUSTAINABLE DEVELOPMENT

EDITORS

Esteban Burbano ERAZO
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**FROM GENES TO SOCIETY:
MULTIDISCIPLINARY STUDIES ON SUSTAINABLE
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**Edited By
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adopted by Esma AKSAKAL

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PREFACE

This book brings together a diverse collection of research that reflects the complexity and interconnectedness of today's scientific and social challenges. From agricultural innovation to environmental sustainability and public health awareness, each chapter offers a distinct lens through which readers can explore pressing global issues.

The first two chapters focus on plant science, examining the genetic and nutritional profile of chickpeas and the adaptive responses of tomatoes to shaded environments. These studies provide valuable insights for improving crop resilience and optimizing food production systems. The third chapter shifts to environmental concerns, offering a comprehensive review of waste management and land reclamation strategies that support ecological restoration.

Finally, the book concludes with a chapter on menstrual hygiene awareness among journalism students, highlighting the importance of cultural and religious perspectives in health education. Together, these chapters underscore the value of interdisciplinary research in shaping a more informed, sustainable, and inclusive future.

Editorial Team
October 06, 2025
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CHAPTER 1
***Cicer arietinum* L. (CHICKPEA): TAXONOMY, GENE
POOL, PRODUCTION, NUTRITIONAL
COMPOSITION, AND BIOACTIVE MOLECULES
CONTENT**

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INTRODUCTION

Consisting of the edible seeds of group of legume crops, pulses as defined by the organization of the United Nations (FAO) as dry harvested leguminous crops, including different varieties of beans, peas, lentils and chickpeas. They are referred as the “meat for poor men” (Begum et al., 2023) due to their widespread consumption in low meat consuming countries (Hall et al., 2017). Pulses hold a significant place because in diets due to their high values of proteins, vitamins and minerals, making them an important balanced diet. Additionally, their bioactive compounds contribute to pulses’ role in addressing various chronic diseases (Marinangeli et al., 2017), mitigation climate change, and sustainable agriculture, since they can be grown in all types of soil.

With the world population expected to reach 9 billion by 2050, there is a growing need for a fiber-rich nutritious based foods. This has led to a pressing demand to level up the crops productivity through methods such as plant breeding aimed at developing cultivars with higher grain yields and enhanced nutritional value (Rajpal et al., 2016).

Cicer arietinum. L also known as cultivated chickpea, is the only cultivated species within the genus *Cicer*, belongs to the family Fabaceae. This self-pollinated, diploid, annual grain legume crop comprises two subspecies known as “kabuli” and “desi” chickpeas (Rajpal et al., 2016). Chickpea, also known as garbanzo beans, was among the earliest domesticated grains of the legume family in the ancient world. Its nutty flavor and versatile applications in foods have led to its incorporation into many culinary creations (Wallace et al., 2016). Globally, chickpea is the third most produced legume, yielding approximately 1.05 ton/ha. India dominates this position with 73% of annual production. Additionally, Algerian chickpeas have a long history of chickpea cultivation before colonization and been used in daily life in culinary preparations, positioning Algeria as the second-largest producer in Africa after Morocco.

Chickpeas are considered a nutrient-rich and functional legume for human consumption, offering potential health benefits. Their nutritional value has been documented in numerous studies. In developed countries, chickpeas are considered a crucial seed food due to its special composition.

In fact, they serve as a good source of carbohydrates, as well as minerals such as calcium, magnesium and potassium, along with vitamins like C and A. Moreover, chickpeas contain a range of isoflavones and carotenoids, and they are low in anti-nutritional factors (Begum et al., 2023; Xiao et al., 2023; Kumari, 2023). Chickpea consumers benefit from increased intake of dietary fibers, carbohydrates (available and unavailable ones), polyunsaturated fatty acids and 18 types of proteins, 8 of which are essential (Zia-Ul-Haq et al., 2007) distinguishing chickpeas as superior among other pulses.

Furthermore, the high dietary fiber content in chickpeas has been shown to lower cholesterol levels and prevent blood sugar from increasing after a meal, making them safe and healthy for diabetic patients. Additionally, chickpeas contain a various composition of bioactive compounds with unique biological activities (antioxidative, antimicrobial, estrogenic, anti-inflammatory, anti-cancer...) and an affective role against different chronic diseases such as cancer, diabetes, hypertension, osteoporosis nervous system disorders. Phenols are among the bioactive compounds found in chickpeas (Kumari, 2023). Therefore, this review studies how the rich composition of chickpea which varies based on geographical origin and harvest conditions, plays a crucial role preventing chronic diseases and mitigating critical health condition in the human body. The study delves into the mechanism by which the bioactive compounds in chickpea seeds function to effectively protect human health, highlighting their importance as a functional food in promoting long-term health.

1. TAXONOMY

Chickpea (*Cicer arietinum*), the only species under genus *Cicer* domesticated, belonged to the Leguminosae family (also known as Fabaceae or Papilionaceae), specifically within the subfamily Papilionoidea or known also Faboideae, before belonging to its own monogeneric tribe the *cicereae* Alef (Table 1), the genus *Cicer* was classified in the tribe *Vicieae* Alef (Kupicha, 1981).

Table 1. Taxonomic hierarchy of chickpea (Van Der Maesen et al., 2007; Ruggiero et al., 2015)

Taxa	Nomenclature
Kingdom	Plantae
Phylum	Tracheophyte
Class	Magnoliopsida
Order	Fabales
Family	Leguminosae
Subfamily	Papilionoideae
Genus	Cicer
Section	Monocicer
species	arietinum

According to Rajpal et al. (2016), the genus *Cicer* contains approximately 49 taxa, with 9 of them being annual species. these 49 species have been categorized based on their morphological characters and geographical distribution into two subgenera *Pseudononis* and *Viciastrum*, along with four distinct sections. Chickpea falls within the *Monocicer* section along with *Chamaecicer*, *Polycicer* and *Acanthocicer* (L.J.G. VAN DER MAESEN, 1987). However, an updated subgeneric classification was proposed by Davies et al. (2007) which introduce a new categorization of different *Cicer* taxa. This new classification system, include three subgenera, five sections and two series, in order to understand the diversity and the relationship within the genus (Table 2).

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Table 2. Subgeneric classification of different Cicer taxa (Davies et al., 2007)

Subgenus	Section	Serie	Species
Cicer	Cicer	Cicer	<i>C. arietinum</i> L., <i>C. echinospermum</i> P.H. Davies, <i>C. reticulatum</i> Ladiz.
		Pinnatifida	<i>C. bijugum</i> Rech.f., <i>C. judaicum</i> Boiss., <i>C. pinnatifidum</i> Jaub. Sapach
	Chamaecicer		<i>C. atlanticum</i> Coss. Ex Maire, <i>C. incisum</i> (Willd.) K. Maly
Viciastrum	Annua		<i>C. chorassanicum</i> (Bunge) Popov, <i>C. yamashitae</i> Kitam
	Polycicer		<i>C. floribundum</i> Fenzl., <i>C. graceum</i> Orph., <i>C. heterophyllum</i> Contandr. Pamuk C Quezel, <i>C. isauricum</i> P.H. Davies, <i>C. montbretii</i> Jaub. and Spach.
	Vicioides		<i>C. acanthophyllum</i> Borris, <i>C. anatolicum</i> Alef., <i>C. balcaricum</i> Galushko, <i>C. baldshuanicum</i> (Popov) Lincz., <i>C. fedtschenkoi</i> Lincz., <i>C. flexuosum</i> Lipsky, <i>C. grande</i> (Popov) Korotkova, <i>C. incanum</i> Korotkova, <i>C. korshinsky</i> Lincz., <i>C. laetum</i> Rassulova and Sharipova, <i>C. luteum</i> Rassulova and Sharipova, <i>C. macracanthum</i> Popov, <i>C. microphyllum</i> Benth., <i>C. multijugum</i> Maesen, <i>C. nuristanicum</i> Kitam, <i>C. paucijugum</i> (Popov) Nevski, <i>C. pungens</i> Boiss, <i>C. rassulovie</i> Lincz., <i>C. rechingeri</i> Podlech, <i>C. songaricum</i> Steph. Ex DC, <i>C. stapfianum</i> Rech.f, <i>C. subaphyllum</i> Boiss, <i>C. tragacanthoides</i> Jaub and Spach.
Stenophylloma			<i>C. canariense</i> A.G. Guerra and G.P. Lewis, <i>C. cuneatum</i> Hochst. Ex A. Rich

Cultivated chickpeas falls into two types “desi” and “kabuli”, which differ from each other by their phenotypic characteristics and end uses (Fig.1). Desi chickpeas feature pigmented plants with smaller, dark-colored seeds and a thick seed coat. In contrast, Kabuli type is associated with light-colored, larger sized seeds with thinner seed coats (Penmetsa et al., 2016). These distinct characteristics define the two chickpea varieties.



Figure 1. Phenotypic variation in chickpea
kabuli chickpeas: simple leaves (a), white flower (b), small seeds (c) desi chickpeas:
compound leaves (d), purple or pink flowers (e), big seeds (f). reproduced from
(Kalve & Tadege, 2017) under Creative commons (cropped image).

2. GENE POOL AND HYBRIDIZATION

The classification of various annual cicer species is based on the gene pool structure, serving as the basis for determining the strategy in hybridization breeding programs. Several authors, as evidenced by Mondal et al. (2020), have proposed this structure as a result of the crossability between different species. Thus, the growing need for cultivars with enhanced yield as well as resistance to diseases, insects, wilts and drought has led to a primarily focus on the closest species to the crop within the gene pool, hence using the gene pool concept the one specific to chickpea may be characterized as follows:

Table 3. Chickpea gene pool (Harlan & De Wet, 1971)

Crop = GP1a	GP1b	GP2	GP3
<i>Cicer arietinum</i>	<i>C. echinospermum</i>	<i>C. bijugum</i>	Other <i>Cicer</i> species
		<i>C. judaicum</i>	(Annual and perennial)
	<i>C. reticulatum</i>	<i>C. pinnatifidum</i>	

As outlined in Table 3, three annual species, namely *C. arietinum*, *reticulatum* and *C. echinospermum* are crossable, allowing the transfer of traits through conventional hybridization. The species in GP1b are more closely related to chickpea compared to those in GP2 and GP3, which are distantly related. *C. arietinum* readily crosses with cultivated chickpea, facilitating regular gene exchange, while *C. echinospermum*, the secondary gene pool, has a similar capability, but resulting hybrids and progenies exhibit reduced fertility. The tertiary gene pool comprises other species, both annual and perennial, that are not crossable with cultivated chickpea.

Special techniques, including hormonal treatment to prevent abscission and embryo rescue, are required to transfer genes into the cultivated background. Moreover, environments with temperature below 25°C, normal humidity levels, and less wind often provide conducive conditions for the successful of wide hybridization activities.

3. CHICKPEA PRODUCTION: GLOBAL CONTEXT

Chickpea is grown all over the world and under varied environmental conditions, spanning approximately 57 countries (Merga & Haji, 2019). Globally, the chickpea yield has reached, in 2021, about 1088 kg/ha. However, the yield in the developed regions which dominates in chickpea production with 80 % of regional contribution, have exceeded that of the developed countries since these last don't contribute much toward chickpea production, the yield is particularly high in some of the European countries. Specifically, the yield in South and Southeast Asia has increased by 13 % from 717 kg/ha in the period of 1994-1996 to 812 kg/ha in 2008-2010, with an annual growth rate of 0.8 % (Merga & Haji, 2019).

Over the period from 2008 to 2017, the Asian global production of chickpea has been substantial, accounting for 83%. Nevertheless, the data shown a slight decline in the Asian share, by 1.9 % to reach 81.1% by the year 2021.

Between 2013 and 2017, around 80 % of Myanmar's chickpea cultivation area was planted with chickpea varieties developed by ICRISAT (The International Crops Research Institute for the Semi-Arid Tropics). This underscores the effectiveness of an advanced crop breeding program and its significant contribution to increased genetic gains. The program involves the selection and breeding of chickpea species with desirable genetic traits to create new generations that exhibit improved characteristics. Over time, the continuing selecting and breeding leads to a higher average performance in the desired traits, and by applying advanced techniques in biology and genomics.

India holds a dominant position in global chickpea production, accounting for about 73 % (10.736 million tons) to the total output, making it the largest chickpea producer worldwide (Fig2). Additionally, the southern part of India specifically, cultivates short-duration chickpea varieties that exhibit resistance to Fusarium. Following India, Australia stands as the second largest global producer with 6 % share.

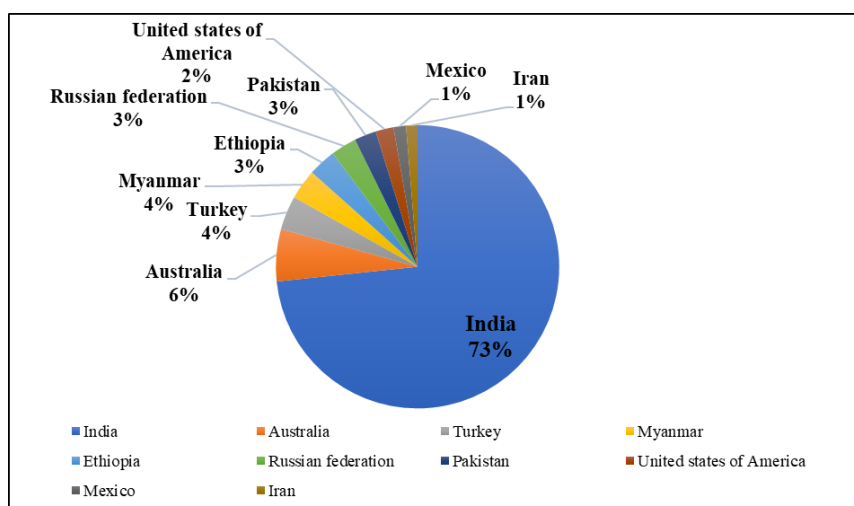


Figure 2. Relative importance of the 10 leading chickpea producing countries in 2021 (Food and Agriculture Statistics, 2021)

According to FAOSTAT (Food and Agriculture Organization (FAO., 2021), the average global production of chickpea has reached 1.05 ton/ha lower than the recent years. Notably, the average yield in the West and South Asia stands at only 1 ton/ha. On the other hand, despite the low production levels in other developing countries such as Ethiopia and Mexico, the yield has exceeded 1.8 ton/ha. Yemen has achieved significant yields reaching 2 tons/ha, and similar or higher yield levels prevail in most developed countries.

According to Madurapperumage et al. (2021), chickpea is the third most produced among pulses in the world at 15.87 million tons per annum, 80 % desi and 20 % Kabuli (Merga & Haji, 2019). India was the leading global chickpea producer in 2021, followed by Australia, Turkey, Myanmar, Ethiopia, Russia, Pakistan, and United States of America (Food and Agriculture Organization (FAO., 2023) (Table 4). Due to the large-scale amount produced by India of chickpeas, Asia has been dominating the global chickpea production over the years till 2021 compared to the Americas (84.4 vs 2.9 %, respectively) (Food and Agriculture Organization (FAO), 2023).

Table 4. Top 10 producers of chickpeas, the grain yields (2017 – 2021)
(FAO., 2023)

Country	Production (T)	Yield (T/ha)
India	10,736,648	5.3233
Australia	873,005.83	6.0157
Turkey	567,000	5.8569
Myanmar	502,026.29	6.807
Ethiopia	465,864.64	10.2222
Russian federation	430,637.12	4.4712
Pakistan	366,348.2	1.9364
United states of America	299,634	7.2695
Mexico	208,274.31	9.7321
Iran	190,494.76	2.0513

Over the past two decades, there has been a general correlation between the harvested area and chickpea production, both exhibiting an overall increase over time, except for lower production in 2015 and 2019 as reported by FAOSTAT in 2023 (Food and Agriculture Organization (FAO), 2023).

Despite its significant scale of production, India has a lower yield compared to smaller producers like Ethiopia and Mexico. This factor contributes to India's status as the world's largest chickpea importer (Merga & Haji, 2019; Food and Agriculture Organization (FAO., 2023). In the last five years, India's imports have shown a decline, dropping from 0.37 million metric tons (MT) in 2019 to 0.23 MT in 2021. This trend coincides with the decrease in yields in 2021 (1.08 MT) compared to 2019 (1.14 MT).

4. CHICKPEA PRODUCTION IN ALGERIA

With a cultivated area of 35,520 ha and a production quantity reaching 38,818 tons by 2021, Algeria stands as the second-largest chickpea producer in Africa after Morocco. Morocco has dedicated about 63,411 ha which explains the high production quantities (72,547 tons) according to FAOSTAT (Food and Agriculture Organization (FAO., 2023). Globally, Algeria ranks as the 18th producer and the 5th importer. However, despite its noteworthy contribution, Algeria's production remains below the requirements. The main constraints for the high importation are the absence of varieties adapted to Algerian conditions and the ongoing genetic erosion of traditional landraces.

Chickpea cultivation in Algeria was known before the year of colonization (1830), characterized by a high genetic diversity. Nevertheless, as stated by Bellemou et al. (2020), the majority of the landraces have disappeared due to lack of management and/or conservation of genetic resources. The chickpea cultivation started rising slowly and effectively from the year 1940; however, this particular species has received little interest in the field of plant genetic resources preservation and characterization studies.

In Algeria, chickpea is traditionally cultivated in spring, and the major constraints affecting yield are heat and drought stresses. The winter varieties have been introduced to increase production, but their sensitivity to humidity, cold damage, and diseases poses additional constraints. Efforts have been made to develop chickpea varieties that present resistant to both cold and *Ascochyta* blight, caused by the pathogen *Ascochyta rabiei*, and significant progress have been attained.

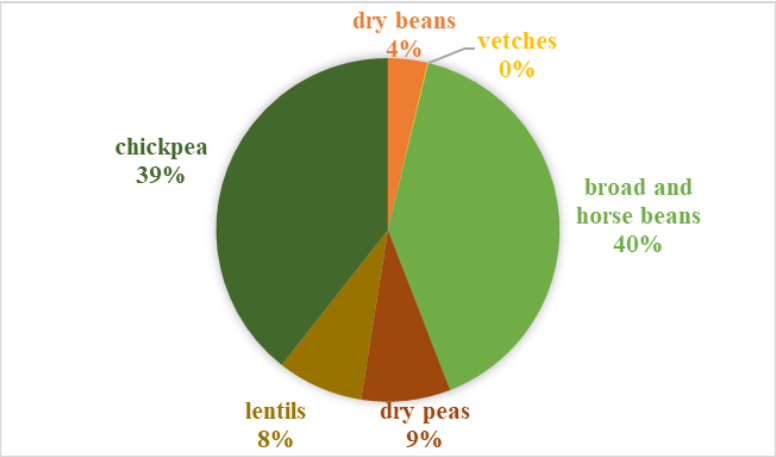


Figure 3. Pulse production in Algeria of the year 2021 (MADR, 2021)

According to the Ministry of Agriculture and Rural Development (MARD), chickpea ranks as the second most produced pulse in Algeria (38,818 tons), closely following broad and horse beans (39,629 tons) with a minimal margin (Fig 3). Additionally, it has been reported a modest decrease of around 3 % in chickpea production in 2019, compared to the figures from the year 2020.

Algeria’s northern region accounts for most of the area cultivated with pulses, with the north-western part dominating, contributing over 52.83 %. Chickpea is primarily grown in coastal areas and inland plains. The leading provinces (wilayas) contribution to chickpea production in the northern region are as follows: Tlemcen (18.67 %), Aïn Temouchent, (13.02%), Mila (8.52 %), and Mascara (6.32 %) (Fig. 4).



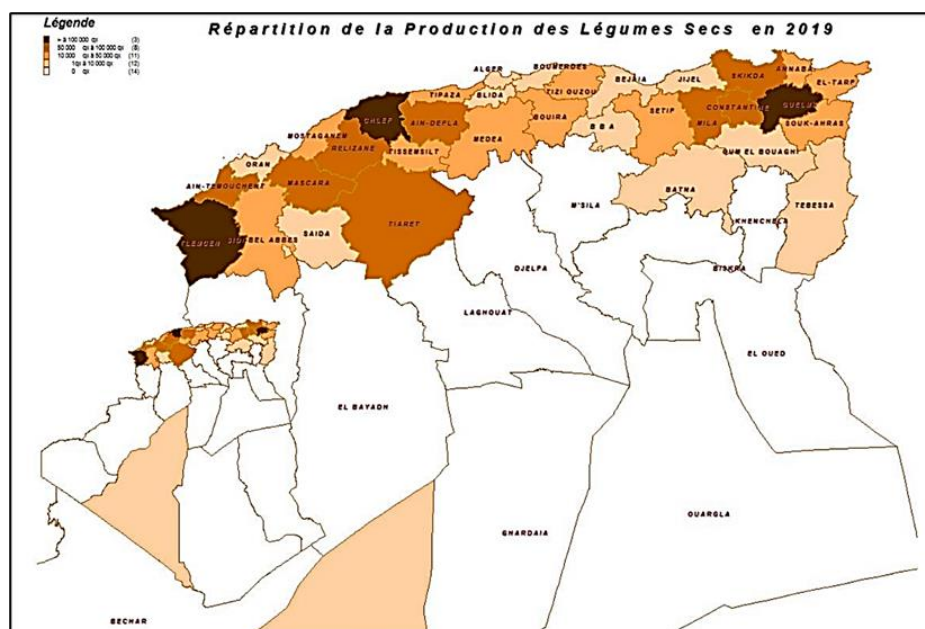


Figure 4. Pulses production repartition in Algeria in 2019

5. CHICKPEA NUTRITIONAL CONTENT

Chickpeas are a good source of energy, protein, minerals, vitamins, fibers and bioactive compounds as phytochemicals, their seeds contain antinutritional factors, which are usually reduced by different processes like cooking and germination. Many factors contribute in the seed's nutritive quality such as environment, climate, soil, biology, agronomic practices and stress factors (biotic and abiotic) (Yadav, 2007).

The two distinct varieties of chickpea, desi and kabuli feature different morphological properties, resulting in the variation in their nutritional compositions. The desi variety has a seed coat that constitutes 14 % of the total mass of the grain, with a net seed weight ranging from 0.1 g to 0.3 g. Whereas, for the kabuli type, the seed coat represents 5% of the total seed weight, ranging from 0.2 g to 0.6 g (Begum et al., 2023).

Table 5. Nutritional composition of chickpea seeds

	<i>Desi type</i>	<i>Kabuli type</i>	References
Proteins (%)	22.2 - 31.5%	15.7% - 23.4%.	(Begum et al., 2023)
Carbohydrates (%)	51- 65%	54 -71%	(Yadav, 2007)
Ash (%)	3.47 – 3.75 %	3.45 – 3.48 %	(Costantini et al., 2021)
Lipids (%)	2.80 – 3.90 %	2.86 – 4.47 %	(Costantini et al., 2021)
Moisture (%)	6.85 - 8.69	6.89 - 7.91	(Ghribi et al., 2015) (Xiao et al., 2023)
Dietary fibers (%)	18.15 – 29.82	7.94 - 11.26	[20]; [23]
Energy (kcal/100g)	334 – 437	357 – 446	(Yadav, 2007)

5.1 Protein Content

As stated by Yadav, (2007), legumes, in general, possess a high protein or nitrogen content. This is owing to their ability to fix the atmospheric nitrogen through the symbiotic association with soil microbes. Table 5 shows that the desi type exhibits the highest protein content compared to that of kabuli type.

According to Grasso et al. (2022), the primary proteins in chickpeas include albumin, globulin, prolamin, and glutenin. The amino acid profile of chickpeas is a key factor in its nutritional composition, since it contains the essential ones. However, chickpea is deficient in sulfur-containing amino acids namely, methionine and cysteine, as highlighted by Begum et al. (2023) (Grasso et al., 2022), in arginine and aspartic acid (Barbana & Boye, 2010), and in methionine and tryptophane (Yadav, 2007; Zhu et al., 2024). On the other hand, lysine, a limited amino acid in cereals, is higher in chickpeas. To overcome such amino acids deficiency and meet the dietary protein requirements of individuals, it is recommended, as a solution, to consume pulses along with cereals (Begum et al., 2023; Grasso et al., 2022).

Xiao et al., (2023) emphasized differences in amino acid content between the desi and kabuli types. For illustration, the most abundant amino acids in chickpeas, namely, aspartic acid, glutamic acid and arginine acid were significantly higher in the kabuli type than in the desi type. The content of essential amino acids in kabuli (8.03 g/100g) was greater than that in desi (6.92 g/100g).

5.2 Carbohydrates and Dietary Fibers

Pulses contains about 60 - 70% of carbohydrates on a dry weight basis, they are the major component in chickpea, mainly in the form of starch (47.4 – 66.9%) with the remaining portion consist of soluble sugars, crude and dietary fibers. In chickpeas, fibers' high content is an outstanding feature. They are non-digestible carbohydrates including both soluble (slowly digestible in the colon) and insoluble (metabolically inactive) fiber. These fibers serve as a nutritional source for intestinal bacteria growth through fermentation. They play a crucial role by supporting regular bowel movements and helping reduce constipation (Begum et al., 2023; Grasso et al., 2022). The primary portion of proteins and carbohydrates is concentrated in cotyledons, whereas the dietary fibers are predominantly located in the seed coat (Costantini et al., 2021). Thus, because of its thick coat and fiber content, desi chickpea has higher level of insoluble dietary fibers than kabuli chickpeas (Grasso et al., 2022).

The major classes of carbohydrates are monosaccharides, disaccharides, oligosaccharides and polysaccharides. Chickpea grains contain a high amount of mono, di, and oligosaccharides, while starch is the main carbohydrate. Glucose is the highest among monosaccharides, while sucrose and maltose are the most abundant among disaccharides (Tab 6). The highest oligosaccharide, ciceritol, does not belong to the raffinose family and yet its high amount does not contribute to a flatulence in a significant way (Yadav, 2007). Dietary fibers in chickpea consist of resistant starch, non-starch polysaccharides (hemicellulose and pectic substances) and oligosaccharides, which are classified as unavailable carbohydrates. Additionally, lignin, although not a carbohydrate but a cells component that has a role of preventing cell walls from degradation, is classified among dietary fibers as it is indigestible besides not fermented in the colon.

Table 6. the content of total dietary fibers and carbohydrates of chickpeas
(Yadav, 2007; Ghribi et al., 2015; Begum et al., 2023)

Carbohydrates	Content %	
	Desi	Kabuli
Monosaccharides	<1	
Glucose	0.7	
Fructose	0.25	
Ribose	0.11	
Galactose	0.05	
Disaccharides	/	
Maltose	0.6	
Sucrose	1 - 2	
Oligosaccharides	0.4 – 2.8	1.2 – 3.9
Verbascose	0.019 – 0.4	
Stachyose	0.74 - 25	
Raffinose	0.43 – 3.2	
Ciceritol	2.51 – 43	
Polysaccharides	69.83 – 70.93	67.72 – 70.64
Starch:	32 – 56.3	30 – 57.2
- Amylose (% of starch)	20 - 42	20.7 – 46.5
- Amylopectin (% of starch)	58 - 80	79.3 – 53.5
Non-starch polysaccharides	12.2	8.78
Dietary Fibers	19 - 23	11 - 16
Lignin	1.3 - 17	0.01 – 2.1

5.3 Lipids and Fatty Acids

The beany or the nutty flavor of chickpeas is attributed to their lipids and fatty acids content. Lipids in pulses appears commonly in various forms including sterols, phospholipids (PhL), triaglycerol (TAG), steryl esters and free fatty acids (FFA). Generally, chickpea and pulses are fat free, however, chickpea stands out with a comparatively high value, reaching up to 8.8 %, compared to other pulses (Yadav, 2007). its phospholipids content is about 17 – 20 % and TAG content was 56 – 67 % as reported by Zia-Ul-Haq et al. (2007). According to Bar-El Dadon et al. (2017), the fatty acid content of chickpeas is influenced by the genotype and the environment (season, climatic factors, diseases ...).

Table 7. Total oil content and fatty acid profile of chickpeas

	<i>Desi type</i>	<i>Kabuli type</i>	References
Linoleic acid (% in oil)	45.95 – 61.5	16.4 – 70.4	(Xiao et al., 2023)
Oleic acid	25.91 – 29.19	23.21 – 36.65	(Yadav, 2007)
Linolenic acid	3.15	2.69	(Begum et al., 2023)
Palmitic acid	11.38 – 12.11	17.8 – 21.5	(Costantini et al., 2021; Xiao et al., 2023)
Stearic acid	1.16	1.42	(Begum et al., 2023)
Total lipids (%)	6.10 - 6.98	4.33 - 6.07	(Ghribi et al., 2015)
USFA (% in oil)	84.36 – 35.36	83.39 – 86.34	(Xiao et al., 2023)
MUFA	26.73 - 29	24.14 – 37.46	(Xiao et al., 2023)
PUFA	54.78 – 58.57	48.71 - 67	(Xiao et al., 2023; Yadav, 2007)
SFA	14.64 – 28.8	13.66 - 29	(Xiao et al., 2023; Yadav, 2007)

The majority of chickpea fats are polyunsaturated fatty acids (PUFA), with linoleic and oleic acids being the most predominant. Additionally, chickpea contains monounsaturated fatty acids (MUFA). Linoleic acid has a crucial role in lowering blood pressure and smooth muscles constriction. Its metabolism in tissues produces prostaglandins, hormones responsible for those functions. The saturated fatty acid fraction of chickpeas is represented by palmitic acid and stearic acid (Table 7) (Xiao et al., 2023).

5.4 Minerals (Ash) and Vitamins Content

Minerals are vital components of enzymes and cells, playing efficient role in the defense mechanisms by acting as inhibitors, activators, and regulators of metabolism. Chickpea serves as a valuable source of calcium, manganese, magnesium, potassium, phosphorus, iron and zinc (Table 8), making a substantial contribution to the human diet. It has been reported that the consumption of 100 grams of cooked chickpeas can provide more than 40 % of the recommended daily intake for adults and even more for children (1 to 3 years) in certain minerals (Bar-El Dadon et al., 2017).

These elements play a pivotal role in the human health; iron is crucial for transporting oxygen in the blood, magnesium and potassium are responsible for maintaining healthy blood pressure and muscle function, and they contribute to energy metabolism and cell membrane potential. Phosphorus serves a basic role in human structure and metabolism. Calcium being the third major element in chickpea seeds, contributes 3.7 % and almost 7 % of the daily recommended intake in adults and children, respectively. Calcium is essential in building bone density and limiting the calcium deficiency, particularly for pre-school children, pregnant and lactating women (Yadav, 2007; Bar-El Dadon et al., 2017; Hall et al., 2017; Begum et al., 2023).

Various studies indicated that there are no significant differences in the mineral composition between desi and kabuli varieties. Both varieties contain an adequate amount of minerals that covers the mineral requirements of the human body.

Table 8. Mineral composition of chickpea seeds

Element	Content	References
Minerals (mg/100g)		
Cu	0.13 – 12.2	(Begum et al., 2023)
Fe	2.4 – 51.11	(Zia-Ul-Haq et al., 2007); (Begum et al., 2023)
Mn	71.96-180.06	(Zia-Ul-Haq et al., 2007); (Begum et al., 2023)
Mg	1.03 - 21.30	(Wallace et al., 2016; Bar-El Dadon et al., 2017)
Ca	53.7 - 431.83	(Costantini et al., 2021) ; (Begum et al., 2023)
Zn	1.36 – 6.2	(Sharma et al., 2013); (Begum et al., 2023)
Na	1.83 - 121	(Costantini et al., 2021; Begum et al., 2023)
K	220 - 1333	(Yadav, 2007)
P	168 – 505.1	(Bar-El Dadon et al., 2017; Begum et al., 2023)
Vitamins (mg/100g)		
Vitamin C	4 – 6.5	(Yadav, 2007; Sharma et al., 2013)
Vitamin E	0.35 – 13.7	(Yadav, 2007); (Bar-El Dadon et al., 2017)
Vitamin A	9.6 - 67	(Yadav, 2007) ; (Begum et al., 2023)
Vitamin(µg/100g)	9.0 - 120	(Begum et al., 2023; Yadav, 2007)
Folate (B9)	0.042 – 0.557	(Sharma et al., 2013; Hall et al., 2017)
Riboflavin (B2)	0.173	(Hall et al., 2017; Begum et al., 2023)
Thiamine (B1)	0.290 – 0.580	(Yadav, 2007; Begum et al., 2023)
Niacin (B3)	0.526 – 1.602	(Bar-El Dadon et al., 2017; Begum et al., 2023)
Pantothenic acid	0.2 – 1.9	(Bar-El Dadon et al., 2017; Begum et al., 2023)
Pyridoxine (B6)	0.139 – 0.466	(Bar-El Dadon et al., 2017; Begum et al., 2023)

Although pulses are known to be abundant in water-soluble vitamins such as B vitamins, chickpeas stand out by offering various other water-soluble vitamins including vitamin C. Moreover, chickpeas contain several lipid-soluble vitamins, including vitamin A (Table 8), E (tocopherols and tocotrienols), and K, all of which contribute to maintaining overall health and bolstering immune function (Patil, 2023). According to (Begum et al., 2023), vitamin E, B9, B5, B6, and B2 concentrations in chickpea are highest compared to other pulses. Folate is particularly important for pregnant women as it supports fetal development. Additionally, the presence of pyridoxine and pantothenic acid play essential roles in the synthesis of enzymes and neurotransmitters, as well as the metabolism of fat, carbohydrates, and proteins, thus, contributing to overall human well-being (Bar-El Dadon et al., 2017).

6. HEALTH BENEFITS OF CHICKPEAS

Chickpeas, categorized as dietary food, have demonstrated their efficiency in addressing various diseases through regular consumption. This is attributed to their rich nutritional profile including carbohydrates, dietary fibers, minerals, and vitamins, as well as a plethora of bioactive compounds such as phytic acid, saponin, tannin, trypsin inhibitor, anthocyanin, carotenoid, isoflavones, phenolic acid, and tocopherol. Together, these elements exhibit a wide range of biological activities including antioxidant, antidiabetic, antihypertension, anti-obesity, anticancer, antimicrobial, anti-inflammatory. Accordingly, they play a pivotal role in the protection of the human health against diseases such as hypertension, diabetes, hypercholesterolemia, among others (Wang et al., 2021). Some health benefits associated with these bioactive compounds are provided in Table 9.

6.1 Antioxidant activity

According to (Savic et al., 2019), the antioxidant activity of chickpea seeds is originally attributed to the presence of polyphenols, including tannins and flavonoids (anthocyanins, isoflavones). These bioactive compounds have the ability to prevent oxidative stress through ox-reduction reactions, where they donate hydrogen and neutralize free radicals (Wang et al., 2021).

Due to this ability, polyphenols provide protective effects against cardiovascular diseases. Some studies have determined that some phenolic compound such as p-coumaric acid, salicylic acid, and t-cinnamic, tend to appear after heat processing of chickpea seeds (roasting, boiling) (Gupta et al., 2017). Others have mentioned a boosted antioxidative capacity in polyphenols found in germinated chickpeas.

In addition to carotenoids that plays the role of vitamin A, the other well-known and more powerful antioxidant compound is vit E (α -tocopherol form), which by limiting the oxidation of low-density lipoprotein (LDL) cholesterol, preventing formation of blood clots and protecting cells from free radical damage, it prevents from atherosclerosis, cardiovascular diseases, cancer and cataracts (Yadav, 2007).

Different studies have proved the high antioxidant capacity of chickpeas' bioactive proteins peptides having aromatic amino acids (Val or Leu) and sulfur containing ones (Met and Cys) (Quintero-Soto et al., 2021; Sánchez & Vázquez, 2017).

Table 9. Bioactive Compounds Of Chickpea Seeds And Their Health Effects

Health benefits	Bioactive compounds	References
Antioxidant activity (cardiovascular diseases, atherosclerosis, cancer and cataracts)	Polyphenols: tannins, flavonoids (isoflavones, anthocyanins), <i>p</i> -coumaric acid, salicylic acid, <i>t</i> -cinnamic	(Yadav, 2007; Gupta et al., 2017; Sánchez & Vázquez, 2017; Savic et al., 2019; Quintero-Soto et al., 2021; Wang et al., 2021)
	- Carotenoids	
	- Vitamin A	
	- Tocopherol (form of α -tocopherol), tocotrienols	
	- Bioactive peptides low molecular weight peptides): P ₃ (Asp-His-Gly), P ₈ (Val-Gly-Asp-Ile)	
	- Trypsin inhibitors	
Antidiabetic	- Polyphenols: anthocyanins	(Yadav, 2007; Hall et al., 2017; Costantini et al., 2021; Kumari, 2023; Begum et al., 2023)
	- Dietary phytoestrogens	
	- α -Amylase inhibitors	
	- SPGAGKG* peptide sequence	
	- phytic acid, lectins	
Anti-inflammatory	- Polyphenols: flavonoids (anthocyanins).	(Yadav, 2007; Costantini et al., 2021; Kumari, 2023)
	- α -tocopherol, tocotrienols	
	- Bioactive peptides (hydrophobic peptides)	
	- Trypsin inhibitors	
Antihypertension	- Polyphenols: flavonoids	(Yadav, 2007; Kumari, 2023; Begum et al., 2023)
	- Angiotensin I-converting enzyme inhibitory peptides	
	- Γ -aminobutyric acid	
Weight management	- Polyphenols: flavonoids (anthocyanins).	(Hall et al., 2017; Wang et al., 2021; Kumari, 2023)
	- α -Amylase inhibitors	
	- Lectins	
	- Bioactive peptides	
Anticancer	- Polyphenols: flavonoids (anthocyanins, isoflavones).	(Yadav, 2007; Wallace et al., 2016; Wang et al., 2021)
	- Tocopherol	
	- Saponins, biochanin A, lycopene	
	- Bioactive peptides fragments	
	- Butyrate fatty acid	
	- Canthaxanthin	
Antimicrobial	- Saponins	(Yadav, 2007; Wang et al., 2021)
	- Bioactive peptides	
	- Polyphenols: isoflavones	

6.2 Antidiabetic Activity

Diabetes, a chronic disease characterized by inadequate insulin production in the pancreas, resulting in elevated blood sugar levels. Currently, medications are used to hinder the activity of carbohydrate-digesting-enzymes like α -glucosidase and α -amylase thereby enhancing glucose absorption. However, these drugs may often induce adverse effects such as diarrhea and flatulence (Begum et al., 2023). Bioactive compounds found in food, such as phenols, proteins, amino acids, peptides and flavonoids, exhibit the potential in managing diabetes by aiding in the regulation of blood glucose levels.

The unique composition of chickpea protein along with its amino acids profile, contribute to a low glycemic index GI (which measures the relative ability of foods to affect blood glucose levels). These two factors combined are believed to be positively influence blood sugar regulation by potentially enhancing carbohydrates' bioavailability and absorption rates, which lowers the GI. Furthermore, chickpea has high concentration of amylase and resistant starch. this latter has an extensive polymerization properties, making it more resistant to intestinal digestion and resulting in slower release of glucose into bloodstream, consequently, reducing the demand for insulin (Gupta et al., 2017). Moreover, other factors that causes the impaired starch digestion in the small intestine are the antinutritional components such as: phytic acid, lectins and amylase inhibitors by inactivating the amylase activity.

According to Gupta et al. (Gupta et al., 2017), sprouted chickpeas are rich in phenolic compounds and possess the ability to inhibit the major type-2 diabetes-related enzymes, α -glucosidase and α -amylase, through substances produced during seed digestion. Additionally, Chandrasekaran & Gonzalez de Mejia, (Chandrasekaran & Gonzalez de Mejia, 2022), have used ficin enzyme to hydrolyze and investigate peptides obtained from germinated chickpeas. Three sequences were identified as potential functional food ingredients, with one of them "SPGAGKG: Serine - Proline - Glycine - Alanine - Glycine - Lysine – Glycine" that contains glycine amino acid, demonstrating a significant antidiabetic activity. This peptide exhibited a higher potential inhibition against α -glucosidase and dipeptidyl peptidase-IV (DPP-IV) compared to the other.

6.3 Anti-Inflammatory Activity

When the human body experiences chemical, biological, or physical injury, such as bacterial infections or damaged vascularized living tissue, it responds by protecting itself in a physiological process. This response involves the activation of mediators like interleukins, including tumor necrosis factor (TNF- α). However, excessive, uncontrollable, and recurrent production of these factors can contribute to chronic diseases such as cancer, asthma, obesity, rheumatoid arthritis, cardiovascular diseases, osteoporosis. While steroidal and non-steroidal drugs are commonly used to treat these diseases, their side effects have led to a growing interest in natural-based alternatives (Begum et al., 2023; Jimenez Martinez et al., 2022).

Chickpea seeds are proved to have various bioactive compounds that inhibit inflammation factors (TNF- α , nuclear factor kappa B (NF- κ B)) through different mechanisms. Protein hydrolysates, such as chickpea albumin hydrolysates (CAH), have been identified as a source of bioactive peptides with anti-inflammatory activity as confirmed by Navarro-leyva et al.(Navarro-Leyva et al., 2023). Additionally, Mahbub et al.(Yadav, 2007) have demonstrated the potential use of phenols found in chickpea hulls as ingredients in functional foods due to their effective reduction in the production of inflammatory markers, such as nitric oxide NO. Germinated chickpea protein hydrolysates also contains hydrophobic peptides that reduce the production of nitric oxide (Begum et al., 2023).

Furthermore, Γ -tocopherol has been identified as an effective antioxidant factor against inflammation by reducing the free radical's production (Yadav, 2007)

CONCLUSION

With the growing population and the resulting increase in global food demand, crop productivity is at remarkable growth to meet the population needs. Chickpea (*cicer arietinum*), the sole cultivated species in the genus *Cicer*, is one of the most consumed legumes around the world. The nomenclature of the chickpea is derived from the Greek term *kikus*, meaning force or strength.

Furthermore, based on various factors like seed shape, size, and color, chickpea cultivars are taxonomically categorized into two primary phenotypes: “desi” and “Kabuli” grown in South Asia, Africa, and the Mediterranean countries respectively.

Globally, chickpea cultivation spans about 57 countries, with developed regions leading in. India, the primary producer since 1994, dominates global production (73 %) due to advanced crop breeding programs, yet remains a significant importer due to low yield compared to smaller producers like Ethiopia and Mexico. In Algeria, chickpea is the second most produced pulse in Algeria (38.818 tons), making it the second producer in Africa and the fifth largest importer globally, due to the lack of varieties resistant to local harvesting conditions.

Nutritionally, chickpeas boast a rich profile of both micronutrient and macronutrient. They are an excellent source of energy, protein, minerals, vitamins, fibers, and bioactive compounds such as phytochemicals. The two distinct varieties of chickpea, desi and kabuli feature different morphological properties, resulting in the variation in their nutritional compositions. The desi variety typically has a higher protein content, and the amino acid composition significantly influences its overall nutritional value. Carbohydrates constitute the predominant macronutrient in chickpea (60 - 70%), primarily in the form of starch, along with various mono-, di-, and oligosaccharides. Although lignin is not a carbohydrate, it contributes significantly to chickpeas' nutritional value.

Despite being classified as a low-fat legume, chickpea contains the highest fat content among pulses (approximately 8%), consisting mainly of polyunsaturated fatty acids such as linoleic and linolenic acids, along with monounsaturated and saturated fatty acids.

Chickpea cover up to 40 % of the recommended daily intake for adults and even more for young children (1 to 3 years) in certain minerals. Magnesium, potassium, and calcium are the primary minerals found in chickpea, all of which contribute to maintaining adequate daily mineral intake for both adults and children. Additionally, chickpeas are abundant in both water-soluble and lipid-soluble vitamins, including B-complex, C, A, and E.

The rich nutritional composition of chickpea seeds, combined with their content of polyphenols, flavonoids and bioactive peptides, endows them with high antioxidant properties. These compounds exhibit a board range of biological activities, including antioxidant, antidiabetic, antihypertension, anti-obesity, anticancer, antimicrobial, anti-inflammatory effects. Consequently, regular consumption of chickpeas may potentially mitigate the development and progression of various chronic diseases, such as cardiovascular disorders and type-2 diabetes mellitus.

Thus, incorporating chickpeas into the diet, in different forms, can offer both nutritional and health benefits, highlighting their importance in addressing global food security and promoting overall sell-being.

Declaration

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CHAPTER 2
TOMATO ADAPTATION TO SIMULATED
PROXIMITY SHADE: MOLECULAR,
PHYSIOLOGICAL, AND METABOLIC
PERSPECTIVES

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INTRODUCTION

Tomato is one of the most important crops worldwide, serving as an essential component of the human diet and as a model plant for carotenoid research. This species originated in South America and, after dispersal around the world, became an important source of nutrients and bioactive compounds (Nuez, Prohens and Blanca, 2004; Rodriguez-Concepcion et al., 2018; Rodriguez-Concepcion, Lim and Ha, 2025). The wild relatives of domesticated tomato are adapted to different environments including arid regions under full sunlight and in isolated areas (Conesa et al., 2017). During domestication, these plants were selected for attributes of agronomic interest, such as increased fruit size, improved palatability (Nuez, Prohens and Blanca, 2004; Alonge et al., 2020), and adaptability to cultivation under higher planting densities, which often generate proximity shade. These adaptations influence not only plant architecture but also physiological and metabolic responses (Casal and Fankhauser, 2023; Burbano-Erazo et al., 2025).

Proximity shade involves an enrichment of FR light because this light is reflected by the green tissues of surrounding plants, however, plants still receive the same photosynthetically active radiation (PAR); only the Red:FR ratio (R:FR) is reduced, as shown in simulations under controlled conditions (Pierik and de Wit, 2014; Casal and Fankhauser, 2023; Martinez-Garcia and Rodríguez-Concepción, 2024). Additionally, although many factors influence normal growth under open-field conditions, a shared hormonal response has been observed between simulated proximity shade and agricultural systems with high planting density in tomato, allowing meaningful comparisons between these systems (Burbano-Erazo et al., 2025).

Light reception in plants is orchestrated by photoreceptors, which allow them to perceive and trigger specific responses depending on the light spectrum. Phytochromes (red and FR light), cryptochromes and phototropins (UV-A and blue light), the ZTL/FKF1/LKP2 group (blue light), and UVR8 (UV-B light) are the main photoreceptors. However, evolutionary processes have generated duplication and neofunctionalization in more complex species such as tomato (Canamero et al., 2006; Klar et al., 2007; Zoltowski and Imaizumi, 2014; Fantini et al., 2019; Shibuya et al., 2021; Beatrice et al., 2022; Łabuz et al., 2022).

This dynamic activation triggers molecular mechanisms according to the light conditions in which the plant grows. Under proximity shade (with prolonged FR light supplementation), photoreceptors are inactivated, leading to changes in the regulation of transcription factors (e.g., HY5 and PIFs) (Toledo-Ortiz and Rodríguez-Concepción, 2010; Toledo-Ortiz et al., 2014; Martínez-García and Rodríguez-Concepción, 2024). As is known, transcription factors regulate gene expression due to their ability to bind promoters. In *Arabidopsis thaliana*, HY5 regulates the expression of more than 1,000 genes (Zhang et al., 2011), making it a master transcription factor that regulates multiple plant responses under diverse conditions in a light-dependent manner.

The effect of the quality of light has been extensively studied due to its molecular, metabolic, and physiological effects on plants such as tomato, as well as its role in signaling and the volatilome, which are fundamental for plant-to-plant communication (Cortés et al., 2016; Moreno et al., 2021). In some species, such as *A. thaliana*, simulated proximity shade is considered a stress factor because it disrupts normal growth and reduces the production of reproductive structures (Roig-Villanova et al., 2025). In tomato, however, the response reflects a balance of both positive and negative effects from an agricultural perspective. On one hand, parameters such as productivity, fruit quality, and precocity are enhanced; on the other hand, carotenoid content is reduced, and susceptibility to biotic stresses increases (Courbier et al., 2020; Fanwoua et al., 2019; Ji et al., 2019; Ji et al., 2020; Kim et al., 2019; Li et al., 2024; Shomali et al., 2024; Burbano-Erazo et al., 2025; Vincenzi et al., 2025).

Currently, the effect of FR light in tomato is beginning to be considered due to its impact on plant physiology and its potential agronomic applications. However, many responses remain unexplored, requiring further research to better understand and optimize tomato behavior under FR light, thereby enhancing its use in agriculture. For this reason, we aim to explore tomato responses under simulated proximity shade and to analyze their potential applications in agricultural systems.

1. METHODOLOGY

Reports were analyzed to provide an overview of light perception in tomato plants and the responses triggered under environments with altered light conditions, such as simulated proximity shade, where FR light plays a fundamental role.

Additionally, the response to proximity shade was evaluated in different genetic backgrounds, including MicroTom (a model tomato variety), M82, Ailsa Craig, and Rio Grande. Plant growth was conducted following the methodology of Burbano et al. (2025). Plants were grown under two light treatments: simulated proximity shade (W+FR) and white light (W, control), at different time points after germination (6, 11, and 18 days). The white light treatment provided a photosynthetic photon flux density (PPFD) of $150 \pm 20 \mu\text{mol m}^{-2} \text{s}^{-1}$, using a combination of five Philips MAS LEDtube 1500 mm HO 23W840 and four Philips MAS LEDtube 1500 mm HO 23W830 LED tubes. Simulated proximity shade was achieved by supplementing the white light with FR light (GreenPower LED module HF FR, Philips), which reduced the red to FR ratio (R/FR) to 0.17 while maintaining the same PPFD. Growth chambers were maintained at $25 \pm 1^\circ\text{C}$ during the day and $22 \pm 1^\circ\text{C}$ at night.

Non-destructive quantification of chlorophyll was done with Chlorophyll Dualex (Metos). Carotenoid and chlorophyll quantification was quantified by HPLC-DAD according to the protocol of Barja et al. (2021).

Data were analyzed statistically using R v4.1.0, applying t-tests and two-way ANOVA followed by post hoc comparisons of means.

2. RESULTS AND DISCUSSION

Molecular framework of light sensing in tomato under simulated proximity shade

Plants possess specific photoreceptors that allow them to perceive different regions of the light spectrum (Quail, 2000). This light sensing not only contributes to essential processes such as photosynthesis but also enables the detection of neighboring vegetation (Ballaré, 1999). Depending on the species, these photoreceptors may undergo duplication events, often leading to neofunctionalization.

For example, when comparing two model plants, *A. thaliana* and *S. lycopersicum*, it has been observed that certain photoreceptors in tomato have undergone duplication (Heuvelink et al., 2025; Figure 1). Within the phytochrome family receptors of red (660 nm) and FR light (730 nm), only Phytochrome B has been duplicated, generating two isoforms (Heuvelink et al., 2025). Among these, PhyB1 is the dominant isoform involved in shade-avoidance responses, particularly in elongation, while the other isoform plays mostly redundant roles (Weller et al., 2000; Schrager-Lavelle, Herrera, and Maloof, 2016).

Under these conditions, where light competition is predominant and FR light is enriched due to reflection from neighboring green tissues, photoreceptor inactivation leads to multiple downstream effects (Casal and Fankhauser, 2023). The most evident response to FR light enrichment is plant elongation, a morphological adjustment that increases canopy height and leaf positioning to enhance light capture; however another relevant effect is the attenuation of plant defense responses, including the downregulation of jasmonic acid and salicylic acid signaling pathways (Moreno et al., 2009; de Wit et al., 2013). This reduction in defense represents a negative trade-off relative to the broadly documented benefits of FR light, which include increased yield and improved fruit quality traits (Cagnola et al., 2012; Casal, 2012; Ji et al., 2019; Ji et al., 2020; Kim et al., 2019; Li et al., 2024). These observations highlight how changes in light quality translate directly into physiological and developmental modifications, mediated by a complex network of molecular mechanisms.

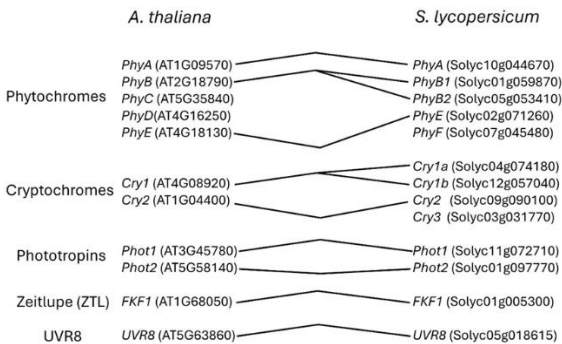


Figure 1. Comparison of photoreceptor gene duplication events between *A. thaliana* and *S. lycopersicum*

Transcription factors regulated by photoreceptors are influenced by FR light enrichment. Among the key transcription factors involved, HY5 and PIFs act as antagonistic regulators (Casal, 2012; Toledo-Ortiz and Rodríguez-Concepción, 2010; Toledo-Ortiz et al., 2014). While HY5 functions as a repressor of genes related to auxin biosynthesis, PIFs act as promoters; therefore, the elongation response under simulated proximity shade is mainly governed by PIF activity (Bou-Torrent et al., 2015; Iglesias et al., 2018). A similar regulatory mechanism is observed in the control of essential enzymes such as Phytoene synthase (PSY), which participates in the carotenoid biosynthetic pathway. This occurs because both PIFs and HY5 can bind to the promoters of PSY, with a negative and positive regulation, respectively (Toledo-Ortiz and Rodríguez-Concepción, 2010; Bou-Torrent et al., 2015). The modification of these transcription factors is a promising strategy to generate positive responses in plants. In the case of HY5, the overexpression of the endogenous version generates an enhancing of carotenoid content in fruits in tomato, being promising for biofortification (Wang et al., 2025). Therefore, manipulating the molecular mechanisms underlying shade responses holds promise for tomato breeding programs.

Adaptive morphological responses of tomato to simulated proximity shade

Proximity vegetation, characterized by a low R:FR ratio, induces modifications in plant growth and development, generating adjustments in plant architecture and physiology in response to altered light quality (Ballaré and Pierik, 2017; Martínez-García and Rodríguez-Concepción, 2024). Under controlled conditions, this type of shade can be simulated by supplementing normal light (W) with FR lamps, which mimic the FR light reflected from surrounding green tissues in dense plant populations. In this simulated proximity shade (W+FR), plant elongation is a key trait associated with the shade avoidance syndrome (Casal, 2012; Ballaré and Pierik, 2017; Casal and Fankhauser, 2023; Martínez-García and Rodríguez-Concepción, 2024).

In seedlings of the MicroTom variety grown under control and simulated proximity shade conditions, elongation was evident in several organs, including the hypocotyl and subsequent internodes, after 6, 11, and 18 days of light treatment (Figure 2A), demonstrating clear shade-avoider behavior. Hypocotyl and epicotyl elongation, commonly used as phenotypic markers in different species, were also assessed in other economically important varieties, such as M82, Ailsa Craig, and Rio Grande, which exhibited similar responses (Figure 2D). The trend of elongation under W+FR was maintained, although variability was observed across genetic backgrounds. These have been observed in MicroTom and other tomato varieties (Burbano et al., 2025).

Other morphological parameters have also been characterized in tomato under proximity shade, including increased stem diameter and greater plant height (Cagnola et al., 2012; Casal, 2012; Shomali et al., 2024; Burbano-Erazo et al., 2025). Some studies suggest that a thicker stem supports larger leaves optimized for light capture and photosynthetic activity (Cagnola et al., 2012). Additionally, cotyledons are larger (Figure 2B-C) after six days of light treatment, and leaves become more expanded (Figure 2B-C; Burbano-Erazo et al., 2025), enhancing the plant ability to capture light in environments with altered light quality and quantity. Reduced leaf thickness allows light to penetrate lower leaves, further improving light perception (Kim et al., 2005). Although these morphological modifications result in larger plants, overall biomass does not appear to change substantially compared to plants grown under normal light conditions (Burbano-Erazo et al., 2025). This growth is accompanied by upregulation of auxin-related genes (Bush et al., 2015; Iglesias et al., 2018; Burbano et al., 2025). Collectively, these responses are characteristic of a shade-avoider plant.

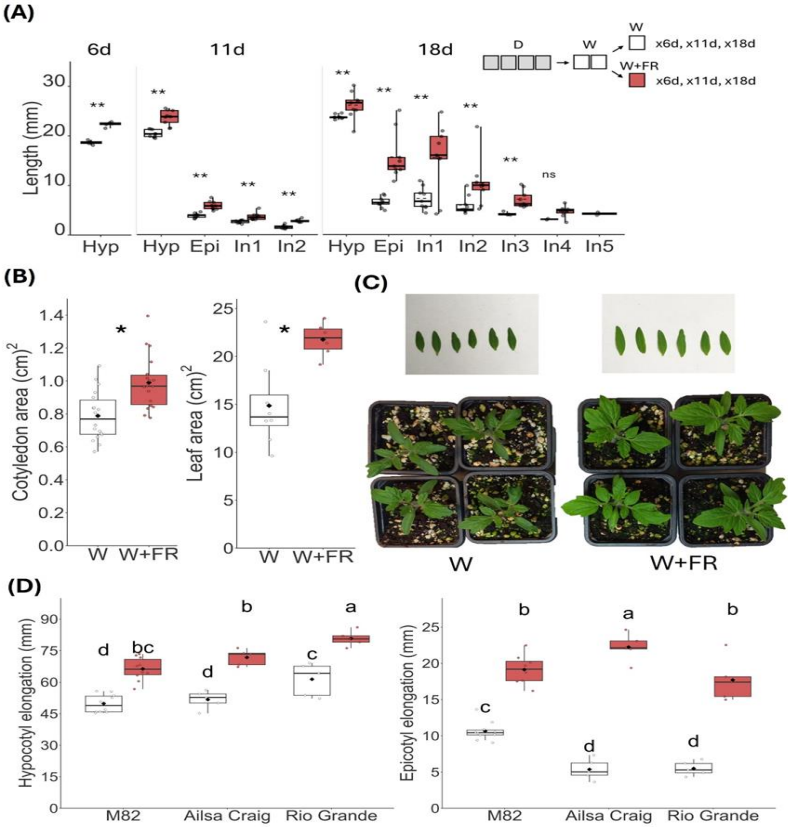


Figure 2. Morphological adaptations in tomato seedlings under W and W+FR (A)

Elongation responses in seedling organs of MicroTom tomato under 6, 11, and 18 days of W and W+FR treatment (Gray boxes: days under darkness; white boxes: days under W light; red boxes: days under W+FR light). (B) Cotyledon and leaf expansion under W+FR. C) cotyledons expansion in seedlings under 6 days of W and W+FR. (D) validation of elongation responses under W+FR in tomato commercial varieties M82, Ailsa Craig and Rio Grande. In all boxplots, each dot corresponds to a biological replicate. The lower edge of the box represents the 25th percentile, while the upper edge corresponds to the 75th percentile. The horizontal black line inside the box indicates the median, and the black diamond shows the mean. Whiskers extend from the box to the minimum and maximum values, excluding outliers.

Statistically significant differences are indicated by letters, based on a two-way ANOVA followed by Duncan's multiple range test ($P < 0.05$).

Light quality and metabolic adjustments in tomato seedlings

Photosynthetic pigments are essential not only for photoprotection in photosynthetic tissues but also for several other functions (Rodríguez-Concepción et al., 2018). For example, carotenoids are required for the pigmentation of structures such as flowers and fruits, playing a key role in attracting pollinators and seed-dispersing animals (Klee and Giovannoni, 2011; Cazzonelli, 2011). In addition, they contribute to nutritional value by serving as a source of antioxidants and as precursors of vitamin A (Bates, 1995; Rodríguez-Concepción et al., 2018). Carotenoids also act as precursors of apocarotenoids, which are generated through carotenoid cleavage mediated by genes such as CCDs (Frusciante et al., 2014; Ahrazem et al., 2016). These apocarotenoids are involved in the production of pigments, aromas, volatiles, and strigolactones, and are essential for plant-to-plant communication (Lewinsohn et al., 2005; Klee, 2010; Frusciante et al., 2014; Kohlen et al., 2014; Moreno et al., 2021).

To analyze the pigments accumulation under W+FR, we first evaluated the reduction in leaf chlorophyll content using a non-destructive method, which revealed a clear decrease under the light treatment (Figure 3a). This reduction was later quantified using liquid chromatography, confirming significant decreases in both leaf carotenoids and chlorophylls in plants grown under W+FR. This response was like the carotenoid reduction observed in seedlings of the model plant *A. thaliana* growing under simulated proximity shade (Bou-Torrent et al., 2015). This result shows that the W+FR can enhance productive parameters, but also clearly reduces carotenoid and chlorophyll contents in leaves (Burbano-Erazo et al., 2025). The magnitude of this effect, however, is strongly influenced by light quality (Burbano-Erazo et al., 2025). This result is possible due to under FR light exposure, photoreceptors are inactivated, and some genes of the MEP and carotenoid pathway are downregulated (Toledo-Ortiz and Rodríguez-Concepción, 2010; Toledo-Ortiz et al., 2014; Martínez-García and Rodríguez-Concepción, 2024; Burbano-Erazo et al., 2025). These results show the effect of W+FR, which leads to a reduction in the accumulation of photosynthetic pigments.

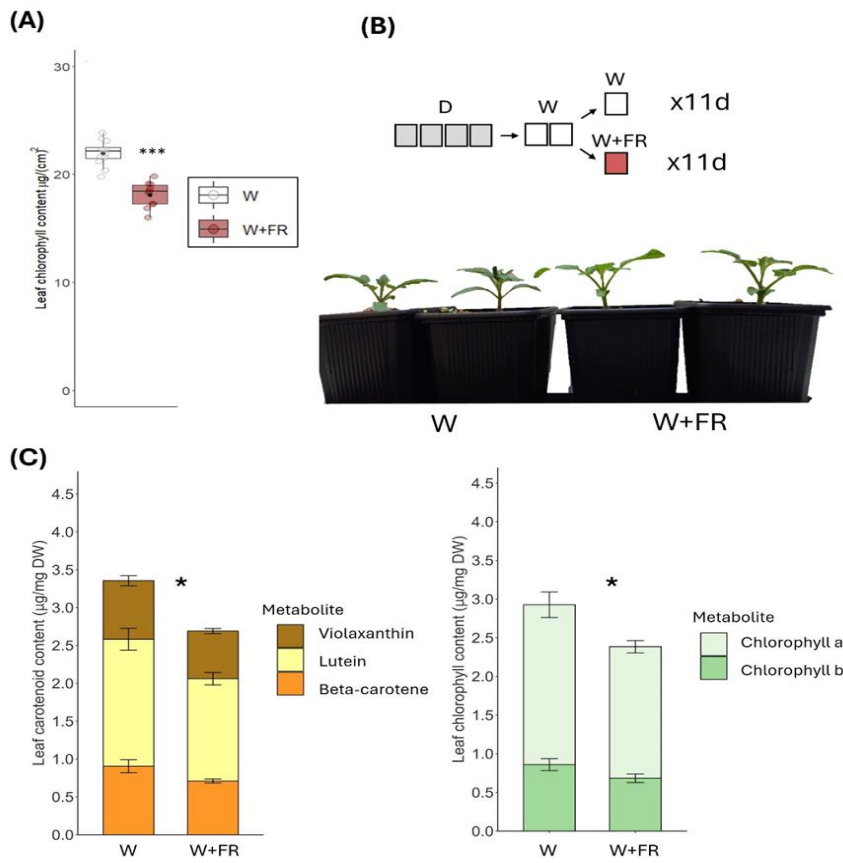


Figure 3. Chlorophyll content in leaves of MicroTom plants under simulated W+FR. (A)

Non-destructive quantification of Chlorophylls in leaves fully expanded under 11 days of W+FR. (B). MicroTom plants and experimental set-up of light treatment, gray boxes: Darkness, white boxes: white light and red boxes: white + FR light, for 11 days (Gray boxes: days under darkness; white boxes: days under W light; red boxes: days under W+FR light). (C) Carotenoid and chlorophyll content in leaves of seedlings under 11 days of light treatment (W and W+FR). Boxplot description as in figure 2. *: indicates a statistically significant difference ($p < 0.05$) according to the t-test.

Antagonistic roles of simulated proximity shade in tomato: increased productivity and abiotic stress tolerance versus biotic stress susceptibility.

Although there are numerous reports showing the benefits of FR light enrichment (W+FR) in tomato, particularly regarding yield parameters and some quality traits as was mentioned above, it is important to consider other impacts generated under these conditions, which remain less widely explored. Some hypotheses suggest that plant defense is reduced because resources are redirected toward growth and fruit yield. This reduction is correlated with decreased levels of jasmonic and salicylic acids, as well as the downregulation of pathways associated with these hormones (de Wit et al., 2013). As a result, tomato plants grown under simulated proximity shade conditions show increased susceptibility to biotic stresses (Figure 4), especially diseases caused by *Botrytis cinerea*, and greater vulnerability to economically important pests such as *Manduca sexta*, *Tetranychus urticae*, *Myzus persicae*, and *Trialeurodes vaporariorum* (Ji et al., 2019; Meijer et al., 2022; Meijer et al., 2023). However, the number of studies addressing this topic is still limited. These responses may also be associated with the reduction in leaf trichome density observed in phyB isoform mutants of tomato, since FR light inactivates this photoreceptor (Cortés et al., 2016). Considering the growing importance of FR light enrichment in tomato, a crop that is massively produced under greenhouse conditions, there is a need for in-depth research to optimize and balance fruit yield with tolerance to biotic stresses.

On the other hand, limited available studies suggests that FR light enrichment can enhance tolerance to specific abiotic stresses (Figure 4), including salinity, calcium nitrate stress, and cold (Cao et al., 2018; Wang et al., 2021; Wang et al., 2020; Zhou et al., 2023; Zhou et al., 2025). This is particularly relevant in regions where soil salinity is a problem, and where excessive fertilizer use further contributes to salinization in large-scale greenhouse tomato production. In this context, FR-enriched environments may offer a balance, as simulated proximity shade not only improves productivity but also enhances tolerance to certain abiotic stresses. Nevertheless, research on these stress responses under light-modified conditions remains scarce.

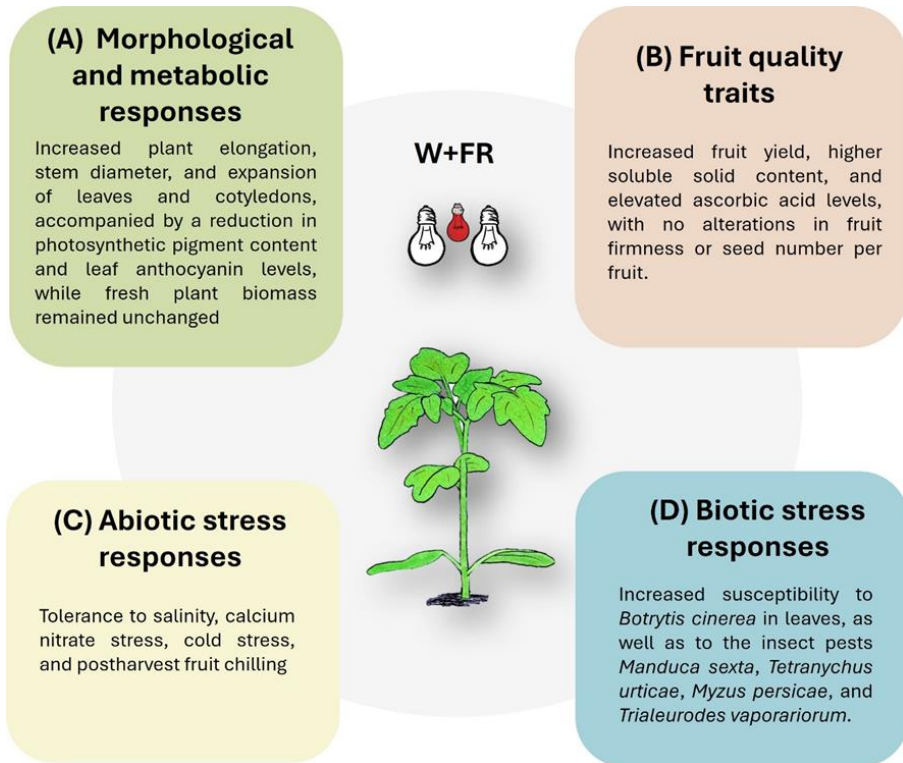


Figure 4. Overview of plant adaptations to prolonged simulated proximity shade in tomato. (A) Morphological and metabolic responses (Cagnola et al., 2012; Chia, and Kubota, 2010; Bush et al., 2015; Burbano-Erazo et al., 2025; Kalaitzoglou et al., 2019; Kim et al., 2019; Li et al., 2024; Shomali et al., 2024; Zhang and Zhang, 2019). (B) Fruit quality traits (Fanwoua et al., 2019; Ji et al., 2019; Ji et al., 2020; Kim et al., 2019; Li et al., 2024; Shomali et al., 2024; Burbano-Erazo et al., 2025; Vincenzi et al., 2025). (C) Abiotic stress responses (Cao et al., 2018; Wang et al., 2021; Zhou et al., 2023, 2025; Wan et al., 2020; Affandi et al., 2020). (D) Biotic stress responses (Ji et al., 2019; Courbier et al., 2020; Meijer et al., 2022; Meijer et al., 2023)

Intensive tomato cultivation requires optimization of both genetic and environmental factors to achieve sustainable agricultural systems. Among environmental cues, light quality is a key factor in regulating normal growth and physiological processes. FR light enrichment, by altering the R:FR, enhances yield and specific fruit quality attributes while also conferring tolerance to important abiotic stresses. However, these spectral adjustments increase susceptibility to biotic stresses.

Therefore, integrating advanced breeding strategies with innovative cultivation technologies is essential to develop resilient tomato production systems.

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CHAPTER 3

WASTE MANAGEMENT, RECYCLING, AND LAND RECLAMATION: A REVIEW

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INTRODUCTION

Recycling has evolved into a major local, national, and international concern. The best method to alleviate garbage disposal difficulties is to limit the amount of rubbish we produce.

The Nigerian government has environmental regulation that requires legislation to instill appropriate attitudes and practices toward the environment (Husemann, 2021). Legislation is a powerful tool for environmental preservation, planning, pollution prevention, and control. Nigerian environmental legislation, such as: (1) National Environmental Standards and Regulations Enforcement Agency (NESREA) Act, (2) Environmental Impact Assessment Act, (3) The Land Use Act, (4) Harmful Waste (Special Criminal Provisions) Act, (5) Hydrocarbon Oil Refineries Act (6) Nuclear Safety and Radiation Protection Act and (7) Niger-Delta Development Commission (NDDC) Act. Recognizes the importance of environmental improvement and protection and creates provisions for the Nigerian State to improve and safeguard Nigeria's air, land, water, forest, and wildlife (Onyinyechi et al., 2016).

Environmental Standards and Regulation Enforcement Agency (NESREA) ACT 2007, The National Environment Standards and Regulation Enforcement Agency (NESREA) Act of 2007 replaced the Federal Environmental Protection Agency (FEPA) Act. It is overseen by the Ministry of Environment. It is the manifestation of rules and regulations aimed at protecting and developing the environment and its natural resources in a sustainable manner.

The National Effluent Limitation Regulations require industry facilities to have anti-pollution equipment for effluent treatment, prohibits the release of hazardous substances into Nigeria's air, land, or water beyond approved limits set by the Agency, requires a discharge to be reported if it occurs, and requires a comprehensive list of chemicals used in production to be submitted to the Agency (Ahmad, et al., 2014)

Section 1 of the Federal Solid and Hazardous Waste Management Regulations (1991) requires industries to identify solid hazardous wastes that are hazardous to public health and the environment and to investigate the possibility of recycling them. It also requires industries to notify the Agency of any discharge and imposes penalties for violating any regulation (Yuan, et al., 2018).

Act on Environmental Impact Assessment (EIA). LFN 2004, CAP E12. According to Wikipedia, an Environmental Impact Assessment (EIA) is a study of the potential effects of a proposed project on the natural environment, whether good or negative: The E.I.A Act, as it is colloquially known, governs environmental impact assessments for both public and commercial undertakings.

The Harmful Waste (Special Criminal Provisions) Act CAP H1, LFN 2004 forbids carrying, dumping, or depositing harmful waste in Nigeria's air, land, or waterways without lawful authorization.

Section 6 punishes violators with life imprisonment as well as confiscation of land or anything used to conduct the offense. Section 7 provides for the appropriate punishment of any conniving, complicit, or negligent officer where the offence is perpetrated by a firm. Section 12 defines an offender's civil culpability. He would be accountable to anyone who was injured as a result of his criminal behavior (Onyinyechi, & Ihendinihu, 2016).

Environmental Sanitation Law

This is a Lagos State statute concerning environmental sanitation and protection. It punishes in varied degrees offenses such as roadway blockage, failure to clean sidewalks, cover trash bins, or properly dispose of wastes.

Environmental Pollution Control Law

Section 12 of the Lagos State Laws makes it an offense to discharge raw untreated human waste into any public drain, water course, or onto any land or water (Ijaiya and Joseph 2014). This offense is penalized by a punishment of not more than N100,000 (one hundred thousand naira) and, in the case of a corporation, a fine of not more than N500,000.

This offence is punishable with a fine not exceeding N100, 000 (One hundred thousand naira) and in the case of a company, a fine not exceeding N500, 000.

Because of the increased population in our society, as well as the generation of various types of waste from industrial, domestic, and medical facilities, which leads to pollution of water bodies, air, land, and the entire environment, which causes diseases, it is critical that the society be aware of the dangers and effects of waste accumulation in the environment, as well as be familiar with the Nigerian laws governing waste management in the environment. This necessitates the review of the ways in which waste disposal, recycling and land reclamation should be done effectively to secure the environment and also to creating awareness on the hazardous nature of improper waste management.

1. HAZARDOUS WASTE CLEAN-UP

Hazardous waste is defined as waste that poses a significant or possible harm to public health or the environment. Everyday industry, economic and personal activities generate trash, many of which are detrimental to public health or the environment (Awodele, et al., 2016). Improper trash management might result in contaminated aerosol and debris (Arslan et al., 2020). According to the USEPA, one in every four people lives within four miles of a superfund site (i.e. an unregulated or plentiful) accumulation of hazardous waste in over 90% of the site, posing a threat to the surrounding ecosystem (Grossman, 2007).

Exposure to hazardous waste may result to reproductive and other birth defect, chronic illness such as cancer and respiratory illness, neurological effect and weaken immunity (Manisalidis et al., (2020) and Pfeffer, (1992).

Hazardous waste has become a part of society as the product that has caused it, and with an ever-increasing human demand for technology and energy, countries are struggling to keep up (Cosgrove, & Loucks, 2015).

Finding new and innovative ways to not only minimize but also dispose of hazardous trash is a goal that must be achieved, and the following guidelines may be useful in hazardous clean-up.

1. Bioremediation: This is one of the most recent technologies for disposing of hazardous waste. It entails the employment of natural or recombinant organisms to break down trash. Bioremediation can be used in areas that are prone to contamination from hazardous waste.
2. Incinerator: this is one method of appropriately disposing of hazardous trash. According to the Environmental Protection Agency (EPA), incineration can kill dangerous organisms in hazardous trash, reducing the overall volume of garbage. However, because metal cannot be burnt, other methods must be investigated (Abdulkadir, 2021).
3. Recycling or Reused: this is becoming more popular when it comes to dispose off the hazardous waste. Used oil is a common waste product that is harmful when dumped in to landfill. As such disposing it has become difficult and ever dangerous, compose are now recycling used oil in to other product such as different grade of oil (Swartzbaugh, 1993).
4. Burying hazardous waste is a strategy that is employed but has become less prevalent as hazardous material can contaminate subsurface water. As a result, burying is hazardous.
- 5.Storage: storing hazardous waste until it is no longer harmful is often done, particularly in nuclear industry. The garbage will lose its toxicity over time and will be safe to dispose of in a regular landfill.
- 6.Waste minimization: This is critical since one can limit the amount of waste disposed of by obtaining the right amount of substance to use in the first place. This is genuine paint, oil fuel, cleaning product, and so on. For example, don't buy a 5 gallon of paint if a two gallon will suffice (Kunmin 1997)
- 7.Medical products: Products such as needles should be appropriately disposed of in a disposable system. Blood, for example, is a biohazard that must be appropriately disposed of. The prescribed dosage of medications should be followed, but the remainder should be washed down the drain.
- 8.Emission control: According to Congress' declaration in Title 42 of the United States Code, air pollution prevention is everyone's responsibility.

For example, adhering to emission standards is the only way to dispose of hazardous waste because the less you create, the less you will dispose (Qdais et al., 1997).

2. WASTE RECLAMATION

Reclaiming waste entails recycling waste into something helpful for our daily lives. It is believed that as humans, we do not want garbage or sewage to be our food source, yet society has discovered that recycling waste back to something useful is crucial in addressing the waste problem. However, we detach ourselves from the psychological anguish caused by the waste reclamation machine and alter our perception of our food source (Yuan et al., 2018).

One application for a waste reclamation machine is the utilization of discarded food as livestock feed. It is an excellent approach to reduce waste that might otherwise wind up in a landfill (Gunders & Bloom, 2017). In truth, there are regulations in place, particularly in the United States, for collecting scrap for proper processing and rendering safe for animal consumption (Jayathilakan et al., 2012).

Another form of waste reclamation is water recycling. Study have indicated that, properly treated water is just safe as water from the tap and this is noticed in different countries were several cities supplement portable water supply with treated waste water. Waste water is also used for crop irrigation, this is because it has higher amount of nutrient that are important for crop production and these means that the use of fertilizer may be reduced (Singh et al., 2012). It is observed that treated waste water contain high amount of Nitrogen and Phosphorous

3. TRANSPORTATION OF WASTE

The transport of waste is largely a function of their physical properties of the surrounding matrix and chemical properties.

a) Physical properties: The physical conditions of which they are subjected to and their chemical factors (Yuan et al., 2018). Highly volatile waste is obviously likely to be transported through a tin and most soluble ones are to be carry by water.

Waste will move faster in porous sandy soil than in compacted clay soil. It should be noted that the major physical property of waste that determined their transport is: (1) volatility (2) solubility and (3) the degree with which they are absorbed on the solid or sediment. Waste compounds are commonly reported to dissolve in water in the hydrosphere and, in some cases, in the soil. As a result, the ability of trash to store chemicals is a determinant in its mobility. Although ethyl alcohol evaporates faster than toluene, the vapour of toluene is more easily evolved from solid due to its restricted solubility in water in comparison to ethanol, which is completely mixable with water (Speight, 2011).

b) Chemical factor: they are factors involved in garbage transportation. When inorganic species are examined, this is achievable. Based on their capacity to be retained by clay minerals, inorganic species can be classified into three types. Cd, Hg, Pb, and Zn are elements that are highly retained by clay. Clay retains K, Mg, and NH_4^+ ions significantly, but not Na, Ca, or B ions. The retention of at least three elements is likely biased because they are leached from clay, resulting in a negative or reversed retention (i.e. elution if often observed) (Vesper, et al., 2001). It should be noted that the retention of Fe and Mn is a consequence of their oxidation state, with the reduced form of Mn and Fe being rather poorly retained, whilst the Fluoroxidase form is insoluble and remains on the soil as a solute.

4. SOURCES AND TYPES OF WASTE

Waste is classified on the basis of their sources: There is solid waste, industrial waste, and domestic waste.

Nuclear waste is also known as radioactive waste. They are radioactive waste that is usually produced by nuclear reactors or left over from research projects, medical applications, and nuclear weapon manufacturing (Landa, 2007). Because radioactive waste is toxic to most forms of life, if not all, and the environment, it is always regulated by state human health and environmental agencies (Hu, et al., 2000).

Classification of radioactive waste:

- (a) High level waste
- (b) Low level waste

These two classes are distinguished by their radioactive source and half-life. These materials are potentially hazardous because they release ionizing radiation, which can cause cell damage or death, birth defects, and cancer. The degree of risk varies depending on the level or kind of radioactivity, with some being extremely dangerous in their raw state and others posing little concern under certain circumstances (Zakariya and Kahn, 2014). Radioactivity in medicine Particles and Gamma ray emitters are common in medical waste. A short-lived gamma emitter nucleus, such as titanium-99, is employed in diagnostic nuclear medicine. Many of these can be disposed of by allowing them to deteriorate for a short period of time before disposal. Nuclear Y90 is another isotope utilized in medicine. This medication is used to treat lymphoma for (27 days) (Ramanavičienė et al., 2019 and Landa, 2007)

Industrial Source. Industrial source of waste can contain alpha, beta and gamma emitters. Human processing that exposes or concentrates their natural reactivity, such as coal mining, etc. A large portion of this waste consists of alpha particle emission compounds produced by the decay of uranium and thorium. Some industrial sources are derived from

- (a) Coal contains a small amount of radioactive uranium, barium, thorium and potassium.
- (b) Oil and gas: Radium and its decay products are found in oil and gas industry residues. The sulphur scale from an oil well can be quite high in radium, while waste oil and gas can be extremely high in radon. Because radon has a similar boiling point to propane, the region where propane is treated is frequently one of the most contaminated areas in an oil processing plant (Al-Masri and Shwiekani, 2008).

5. DISPOSAL OF WASTE

In general, "disposal" refers to the act of depositing waste in a landfill for final burial, destruction, or placement for future recovery. As the final action for solid waste pollution control, the ultimate goal of disposal is to isolate solid waste and its environmental impact from the biosphere and to protect people and the environment from any intolerable risk from the infection of dangerous components in wastes (Guangyu, 2009a).

6. OBJECTIVE OF WASTE DISPOSAL

The goal of final disposal is to ensure that wastes cannot be processed and reused. For example, waste from one industrial process could be used as a raw material in another industrial process. The advancement of industrial technologies would allow for the repurposing of historical garbage (Jayathilakan et al., 2012). According to a strict definition, "disposal" refers to activities that reduce or eliminate hazardous components in solid wastes, as well as activities that contain solid wastes in a location or facilities that meet environmental protection standards without the need to isolate from the biological environment. To meet disposal standards, some treatment method affecting the physical, chemical, or biological characteristics of solid wastes, such as composting, incineration, and/or others, would be implemented. When dealing with urban municipal garbage, public participation is critical (Christensen, 2011). There are times when the difficulty experienced by environmental officers in planning and directing a project in a social manner may overshadow the need for technical solutions, particularly in waste disposal, which has a significant impact on environmental quality. In other cases, MSWM decisions are made without sufficient planning, take only some aspects of a situation into account, are based on a short-term view of the situation, or are influenced by policymakers' interests. Overcoming these inclinations will make it much easier to identify the optimal answer in the given circumstances (Portney, 2013). How to choose a technological strategy is linked to many decision-makers in environmental, economic, and social issues across the entire process, from waste minimization to final disposal. The majority of waste management solutions have broader ramifications. This indicates that a technology or policy must strike an acceptable balance of viable, sustainable, ecologically beneficial, and socially sensitive aspects.

Policymakers in these countries should be concerned not just with the absolute avoidance of environmental degradation and/or human risk, but also with making investments that give the maximum return to society. We must arrive to a point where there is a balance of environmental, social, and economic benefits. In each country, waste disposal costs must play a significant role in overall environmental improvement.

The socialization of waste disposal activities would be unavoidable over time (Allesch & Brunner (2014), and Guangyu, (2009b).

The essential concepts of various municipal waste disposal systems, as well as a brief summary, should be described by legislation. Because there are numerous variances in decision-making settings from one location to another, we could not ignore these distinctions and instead try to derive some general findings that may have wide relevance.

7. WASTE REDUCTION

Most cities are concerned about the growing amount of municipal trash. The obvious starting point for solid waste management, based on the "from cradle to grave" management philosophy (also known as Life Cycle Analysis), is to limit the amount of garbage that must be managed (Fernandes et al., 2017). The initial stages in waste management should be to reduce waste and maximize environmentally appropriate trash reuse and recycling. The environmental, social, and economic benefits of incorporating waste reduction strategies are the foundations for an emerging global agenda for solid waste management (Guangyu, 2009b).

Municipal Waste Reduction

Waste reduction, in its broadest sense, is the reduction of wastes that must be collected and disposed of by solid waste authorities in order to keep recyclable and compostable organic materials from entering final waste streams. Some critical topics in this discipline must be clarified (Diaz et al., (2020) and Guangyu, (2009b).

Source reduction: To cut down on solid waste at the source. It is the most active and cost-effective method of reducing municipal waste. Source reduction can be performed in a variety of ways (Guangyu, 2009a). Source separation is the main process which means keeping different categories of recyclable matter and organic matter separate at source, i.e., at the point of generation, to facilitate reuse, recycling, and composting (Daskalopoulos et al., 1998)

- Waste recovery, materials recovery, or waste diversion: Obtaining useful resources from municipal garbage, either by source separation or sorting from mixed wastes that can be reused or recycled. Its basis is trash classification, which implies separating recyclable components before or after they are combined together for collection.
- Reuse and recycling: "Reuse" refers to the act of reusing an undamaged "waste" product for the same or a different purpose. The material recovery process is referred to as "recycling" if the original product has been turned into secondary resources for the manufacture of new items (Singh et al., 2017).

Action for waste reduction can take place in many routes for achieving waste reduction in different stages in a waste stream. It is as follows (Daskalopoulos et al., 1998).

Source Reduction:

- To enhance consumer's consciousness about environmental protection by public education;
- To reduce the quantity of materials used in products or packaging;
- To urge producers of products to accept a degree of responsibility on treatment or recovery of the wastes produced from the products they manage;
- To reduce production and application of perishable consumer goods.

8. SYSTEMS OF WASTE REDUCTION AND MATERIALS RECOVER

The main motivations for waste reduction in affluent countries are the high cost and scarcity of landfill sites, as well as the threat posed by toxic materials in waste. In some developing countries, there are no substantial disposal constraints since they cannot afford to spend more money and effort on the greater quantities of waste that will surely be generated as consumption levels rise.

The disparities in Municipal Solid Waste Management between developed and developing countries can be seen in waste reduction and material recovery. Rising living standards and the wealth of mass manufacturing have

limited markets for discarded materials in the country's prosperous region (Curzio, et al., 1994).

There is a great potential for waste reduction in developed countries, and recycling has endured and the recovery of synthetic or processed materials is now being emphasized. Whereas, in most of the developing world, traditional labor-intensive practices of repair, reuse, and waste trading persist.

In the developing countries, the greatest potential for waste reduction currently rests with diverting organic and construction wastes. The reason is that organic matters are the largest category of Municipal Solid Waste and the greatest reduction in wastes for disposal can be achieved by diverting organic matters (Curzio, et al., 1994).

CONCLUSION

Finally, disposal is the "no alternative" choice since it is the final functional element in the solid waste management system and the ultimate fate of all wastes that have no further use. As the final action for solid waste pollution control, the ultimate goal of disposal is to isolate solid waste and its environmental impact from the biosphere, to limit the infection of hazardous components in wastes to less than acceptable levels, and to ensure the safety of human health and the environment. Source reduction is the most desired activity from the perspective of the community because the community does not incur costs for waste handling, transporting, and disposal for waste that is never created and delivered to the waste management system, and as the patterns of waste generation become more diffuse and the total quantity of waste increases, the logistics of collection become more complex.

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CHAPTER 4

**ASSESSING MENSTRUAL HYGIENE AND ISLAMIC
PERSPECTIVES KNOWLEDGE AMONG
JOURNALISM STUDENTS AT UIN MAKASSAR: A
DESCRIPTIVE SURVEY**

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INTRODUCTION

According to the World Health Organization (WHO), adolescence is between the ages of 10-1 to 19 years (WHO, 2014). Adolescence is a transitional period between childhood and adulthood, where physical changes (growth spurt) occur, secondary sexual characteristics appear, fertility is achieved and psychological and cognitive changes occur (Suryani 2019). Adolescence is the transition from childhood to adulthood. It is during this period that the maturation of human reproductive organs begins and is often called puberty. Adolescence in adolescent girls is characterized by menstruation (Yusiana and Saputri 2016)

Menstruation is a process in which the endometrium or lining of the uterine wall decays due to unfertilized. It usually lasts 5-7 days per month (Larasati, Puspitasari, and Saptarina 2023). Menstruation, or menstruation, is intermittent and cyclic bleeding from the uterus, which is accompanied by removal of the endometrium (desquamation). Menstruation is a major problem for girls and can sometimes cause cramps, weight gain, headaches, back pain, swollen knees and emotional changes (Ilham, Islamy, and Nasution 2023).

Hygienic behavior during menstruation is very important for women to maintain personal hygiene and health, both physical and spiritual. Personal hygiene during menstruation is the first step to understanding personal health, because a clean body will minimize a person's risk of illness (Susanti and Lutfiyati 2020). Complaints due to lack of knowledge about personal hygiene in the form of itching on the vulva, a disease characterized by strong itching of the genitals (Panggabean 2023)

Wanita rarely pays attention to the cleanliness of her external genitals. Vaginal infections affect 10-15% of the 100 million women worldwide each year, for example, about 15% of adolescents with Candida bacterial infections experience vaginal discharge. This is because adolescents do not know about reproductive problems (Nurchandra, Mirawati, and Aulia 2020).

Based on data from the Ministry of Health, cases of vulvar pruritus are most often found in adolescent girls with 5.2 million cases (Kementerian Kesehatan RI 2017).

Previous research conducted by Aini and Afridah (2021) revealed inaccurate vulvar hygiene behavior during menstruation, including the use of not routinely changing pads, using antiseptics or fragrances for female organs, rarely Changing underwear when damp, poor vulvar hygiene behavior, and not using clean water when cleaning the vulva, result in less than 90% of women experiencing vulvar pruritus. Hubaedah (2019) also links that there is a relationship between vulvar hygiene behavior and vulvar pruritus, with the level of behavior in the less category of 63.3% and the level of vulvar pruritus experience of 74.7%.

One of the consequences of not understanding genitals in personal hygiene is reproductive health disorders such as vaginal discharge, urinary tract infections (UTIs), pelvic inflammatory disease (PRP) and the possibility of cervical cancer, therefore very good information about reproductive health is needed, so that the younger generation understands well and can prevent the risk of reproductive diseases (Agra 2016).

According to the Central Statistics Agency (BPS 2021), the main causes of reproductive tract infections (ISR) are poor personal hygiene during menstruation and using unsafe pads or not changing pads regularly. Therefore, genital hygiene must be observed, because bacteria can easily enter and cause genital diseases, which appear like itching caused by *Candida* fungi that multiply during menstruation. The results of Maharani's research (2018) bad behavior in personal hygiene during menstruation are 79.1%, knowledge about poor personal hygiene during menstruation is 58.8%, while knowledge about personal hygiene does not exist. during menstruation up to 6,9%.

The purpose of this study was to determine the picture of personal hygiene knowledge during menstruation in students majoring in journalism UIN Alauddin Makassar.

1. METHOD

The research method used is quantitative research, using descriptive survey methods. This research was conducted online on December 28 - December 29, 2022 using a google form. The implementation technique is carried out by spreading the google form link through social media to the research subject.

The population in this study is 270 female students majoring in Journalism, Faculty of Da'wah and Communication UIN Alauddin Makassar, class of 2020, 2021, and 2022. Then from the population determined samples using purposive sampling techniques and 150 samples were taken.

Data analysis is carried out in a descriptive way, namely by looking at the percentage of data collected and presented frequency distribution tables, then looking for the percentage of answers from each respondent and then discussing using existing literature theory.

Research Results

Table of distribution of respondents based on knowledge of 4 aspects (menstruation, hormonal changes during menstruation, personal hygiene during menstruation and menstruation according to Islam)

Table 1. Distribution of Respondents' Knowledge Based on Four Aspects

Variable	N	%
Menstruation		
Good	99	70%
Less	42	30%
Hormonal changes during menstruation		
Good	95	67%
Less	46	33%
Personal hygiene		
Good	124	
Less	17	12
Menstruation according to Islam		
Good	66	47%
Less	75	53%
Total	141	100%

Based on the characteristics of knowledge of 4 aspects (menstruation, hormonal changes during menstruation, personal hygiene during menstruation, and menstruation according to Islam) 85 people whose knowledge is good with a percentage of 60%. While there were 56 respondents whose knowledge was lacking with a percentage of 40%.

2. DISCUSSION

Menstruation occurs at the age of 10 to 15 years, but there are also those who experience faster or below that age. Menarche that occurs before age 8 is called precox menstruation. Based on a report (Badan Pusat Statistik 2017) shows that the majority of adolescents experience menstruation for the first time at the age of 11 to 14 years or 76.6%. Meanwhile, according to the Indonesian Ministry of Health (2018), the average age of menarche in Indonesia is 12 years and its prevalence is 60%. At the age of 9-10 years it is 2.6%. At the age of 11-12 years it is 30.3% and 30% at the age of 13 years. The rest experience menstruation at the age of over 13 years (Ministry of Health 2018). Based on the results of research that has been done, it can be known that respondents most menstruate for the first time at the age of 14 years as many as 53 people or 38%. This is in line with research conducted by (Yulita, Devitasari, and Delika 2022), showing that of 39, 37 (94.8%) adolescent students experienced menarche at the age of 11-14 years and 2 (5.2%) menarche at the age of <11 years.

Knowledge about menstruation and influential hormones also needs to be understood by young women. At the time of approaching the occurrence of menstruation will arise physical, psychological, and emotional symptoms caused by hormonal changes. Usually it will occur a few days before menstruation and will disappear a few days when menstruation occurs, but also sometimes occurs continuously until menstruation is complete. Hormonal changes will cause premenstrual syndrome (PMS) caused by rising and falling hormone levels during the menstrual cycle (Handayani 2019).

Based on the results of research that has been done, it was found that 99 people have good menstrual knowledge with a percentage of 70%. For knowledge about hormonal changes during menstruation, the results obtained were respondents who had more good knowledge (67%) than respondents who had less knowledge (33%). These results are in accordance with research conducted by (Saadah et al. 2021) which states that the majority of respondents have a very good level of knowledge about menstrual pain self-medication (dysmenorrhea) with 110 respondents (67.9%).

Based on research conducted by respondents, it is seen from personal hygiene knowledge during menstruation, who have good knowledge as many as 124 respondents with a percentage of 88% and who have less knowledge as many as 17 respondents with a percentage of 12%. So, it can be concluded that respondents' knowledge about personal hygiene during menstruation who have good knowledge > from respondents with less knowledge. The results of this study are in accordance with research by (Sitarani, Rumiati, and Sumbayak 2020), stating that the majority of respondents have menarche age which affects the level of knowledge of children with personal hygiene because there is more experience and knowledge gained in the first menstruation.

In fiqh literature, there are four types of female blood, namely menstrual blood, puerperal blood, wiladah blood, and istihahah blood. Menstrual blood comes out regularly every month. Puerperal blood comes out after childbirth. Wiladah blood comes out at the same time as the birth of the baby from the womb. And istihadah blood or disease blood does not come out during menstruation and puerperium, but comes out of the genitals their blood vessels burst. In Islam, menstruating women are forbidden to perform some worship, such as praying, fasting, and reading their Quran to replace it later after menstruation. Although in Qur'an, for example, they are still allowed to perform other worship, such as remembrance to Allah verbally or with their hearts (Muttaqin 2019).

Based on research conducted in terms of menstrual knowledge according to Islam, respondents who have good knowledge as many as 66 respondents with a percentage of 47% and those who have less knowledge as many as 75 respondents with a percentage of 53%. This is in accordance with research (Solehati et al. 2017) proving that 71.33% of adolescents get the first information about menstruation from their mothers, where the information given by mothers to their daughters, depends on the level of knowledge of the mother. Thus, it can be concluded that respondents' knowledge about menstruation according to Islam, which has more or less knowledge than good knowledge.

According to the book of menstrual fiqh (2019) the prohibition on menstruating women touching the mushaf also applies to people with small and other large faces, because touching the mushaf is mandatory with ablution. But according to the plague, scholars agree that the prohibition applies only to people with big faces, while for people who have small faces there is no qat'i argument that explains the prohibition, but most scholars forbid it. Ibn 'Abbas and the Zaydiyyads allowed people of both small and large faces to hold mushaf.

CONCLUSION

From the results of research obtained from data on the picture of personal hygiene during menstruation in journalism students, it can be concluded as follows:

1. Overview of knowledge related to menstruation of Journalism students is included in the good category with 90 people (70%)
2. The description of knowledge related to hormonal changes in Journalism students is included in the good category with 95 people (67%)
3. Overview of knowledge related to personal hygiene of Journalism students is included in the good category with a total of 124 people (88%)
4. The description of knowledge related to menstruation in Islam Journalism students are included in the category of less with the number (66 people 47%)
5. The description of knowledge related to 4 aspects (menstruation, hormonal changes, personal hygiene, and menstruation in Islam) is included in the good category with a total of 85 people (60%)

Suggestion

It is expected that journalism students will gain insight into knowledge related to menstruation in Islam. By reading other literature related to menstruation. Furthermore, researchers can conduct the same research with more varied variables. In addition, the results of this study can be a source of information for other students.

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