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Opuntia ficus-indica (L.) Mill. Pulp Extract Attenuates Glucose-induced Lens Opacity via Antioxidant Mechanisms: An *In Vitro* Investigation

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Abstract

Background: Cataracts cause most reversible blindness. High blood sugar produces oxidative stress, which disrupts proteostasis, depletes antioxidants, and activates the incorrect Hippo signalling pathway, causing lens opacity. Plant extracts high in flavonoids are promising medicinal treatments. Healthy bioactive flavonoids like quercetin, kaempferol, and isorhamnetin are found in the prickly pear plant, *Opuntia ficus-indica* (L.) Mill. (OFI). **Methods:** An *in vitro* goat lens glucose-induced cataract model was used to evaluate a methanolic OFI pulp extract. They retained lenses for 72 hours in six experimental groups. These groups included normal control (5.5 mM glucose), disease control (55 mM glucose), standard medication (enalapril 12 ng/ml), and OFI pulp extract at 250, 500, and 1000 µg/ml concentrations. Photos showed the lens's opacity, and biochemical tests measured total protein and catalase enzyme activity in lens homogenates. **Results:** Lenses in the disease control group were hazy and had lower levels of total protein (2.96 ± 0.48 g/dl) and catalase activity (0.84 ± 0.16 U/min/ OFI pulp extract treatment led to improved lens clarity, as well as increased protein levels (5.11 ± 0.36 g/dl) and catalase activity (1.57 ± 0.10 U/min/g), similar to enalapril. **Conclusion:** *Opuntia ficus-indica* pulp extract has antioxidant and anticataract properties *in vitro*. Its diabetic cataract therapeutic potential needs further study in *in vivo* animal models.

Major Finding: *Opuntia ficus-indica* pulp extract may induce cataracts via aberrant Hippo signaling.

Keywords: Antioxidant, Cataract, Flavonoids, *Opuntia ficus-indica*

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1. Introduction

A cataract is a condition marked by the clouding of the eye's crystalline lens, which reduces transparency and impairs light transmission to the retina. This can lead to gradual vision loss and is caused by changes in lens proteins and fibres that affect its normal focusing ability[1]. Cataracts are the leading cause of global visual impairment, affecting over 13 million people with blindness. Their prevalence is expected to rise due to ageing populations and lifestyle changes[2]. Cataracts significantly impact vision, mental well-being, and quality of life, while also increasing mortality rates and economic burdens. The prevalence of cataracts increases significantly with age. It affects 3.9% of individuals aged 55 to 64, but this percentage rises to 92.6% in those aged

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80 and older. Cataracts remain a major cause of blindness, particularly in low-income countries, where they account for 50% of blindness cases, compared to only 5% in developed nations[2-4]. A significant public health concern, especially in older populations, cataracts continue to be the primary cause of reversible blindness globally. Age, oxidative stress, UV light, metabolic diseases, and genetic mutations have all historically been implicated in the aetiology of cataracts. Recent developments in molecular ophthalmology, however, indicate that the development of cataracts is a complex and dynamically controlled process that involves proteostatic imbalance within lens fibre cells, metabolic sensing, and disruption of intracellular signalling networks. Disrupted inter-organelle communication in lens epithelial and fibre cells may lead to cataracts through progressive proteome instability. Ageing, metabolic stress, and UV exposure compromise mitochondria-endoplasmic reticulum interactions, resulting in metabolic reprogramming, reduced antioxidant regeneration, and increased reactive oxygen species[5,6]. This imbalance creates calcium microdomains that activate calpain proteases, causing crystallin fragmentation and destabilising cytoskeletal structure. Additionally, epigenetic changes reduce chaperone protein expression, further accelerating protein aggregation and lens opacity. Overall, cataract development is attributed to a coordinated failure in metabolism, structure, and proteostasis rather than isolated oxidative damage[7,8]. Under chronic oxidative stress, the regulation of the Hippo signalling pathway has a significant impact on the molecular progression of cataract formation. By blocking AMPK, oxidative stress starts a pathological cascade that suppresses LATS 1/2 activity and "shuts off" the Hippo pathway. This condition makes it easier for dephosphorylated YAP/TAZ to build up inside the nucleus. The ensuing nuclear translocation causes YAP/TAZ target genes to become overactive, which causes fibrosis and the Epithelial-Mesenchymal Transition (EMT) in Lens Epithelial Cells (LECs). These molecular changes show up as aberrant cellular proliferation, which eventually leads to cataract development and lens opacity[9,10]. On the other hand, flavonoid-based therapeutic intervention shows a protective mechanism through strong antioxidant action in the lens epithelium. By lowering Reactive Oxygen Species (ROS), lipid peroxidation, and protein oxidation, flavonoids prevent cellular damage and stabilise ATP levels. AMPK is activated, and its sensitivity is restored by this metabolic stabilisation. After activation, AMPK promotes the activation of LATS 1/2 and MST 1/2 phosphorylation by stimulating the Hippo core kinases. The Hippo "on" state is restored by this reactivation, which causes YAP/TAZ to be phosphorylated and retained (or degraded) in the cytoplasm. This pathway preserves LEC homeostasis and successfully inhibits the development of cataracts by inhibiting lens-damaging genes linked to EMT and fibrosis and concurrently activating Nrf2 to stabilise crystallins. Cataracts are diagnosed through visual acuity tests, which measure clarity of vision, and slit lamp examinations, which identify lens opacity and determine the cataract type and severity. Ophthalmoscopy assesses retinal health, while additional tests like tonometry and contrast sensitivity evaluations help identify related ocular complications[9-12]. The Cactaceae shrub *O. ficus-indica* (L.) Mill. (OFI) pulp, commonly known as the prickly pear or pear bush, grows to 1-1.8 m. Juicy. Tropical, subtropical, desert, and semi-desert conditions can support *O. ficus-indica*. Small leaves resemble cylindrical spines, and flowers are lemon-yellow to golden orange. Green fruits turn scarlet when mature. Cladode and fruit surfaces have glochids. Due to *O. ficus-indica*'s many bioactive substances, pharmacological characteristics have been studied extensively. *O. ficus-indica*'s fresh fruit and lyophilised aqueous fruit extract both reduce hyperglycemia and inflammation. *O. ficus-indica* possesses more minerals than other fruits, including salt, calcium, magnesium, manganese, ash, ascorbic acid, total phenolics, and fibre. The key chemical components are 3-O-methyl quercetin, kaempferol, kaempferide, quercetin, isorhamnetin, and β-sitosterol. The *O. ficus-indica* pulp was tested for anticataract inhibition in a goat lens glucose-induced cataract *in vitro* model. Antioxidant and cataract-preventive properties were also examined, focusing on lens structure, protein content, catalase activity, and antioxidant activity[13,14].

2. Experimental Materials and Procedures

2.1 Collection and Verification of Plant Material

Pulp of *Opuntia ficus-indica* (L.) Mill. were collected from Vadodara city. The plant specimen was subsequently

authenticated by the Department of Botany at the School of Science, RK University in Rajkot, Gujarat.

2.2 Preparation of Plant Extract

Seven hundred grams of the pulp were converted into a liquid form and macerated in methanol for 48 hours. The resulting extract was dried by evaporation at 40°C and subsequently stored at 4°C. Preliminary phytochemical screening was then conducted to assess the presence of constituents such as flavonoids, glycosides, and phytosterols, following previously established protocols[15].

2.3 Chemicals and Reagents

The total protein and catalase were measured by biuret colourimetric methods. Every additional chemical that was utilised in this investigation was of analytical quality.

2.4 Collection of Goat Eye and Lens Culture

For this study, we sourced fresh goat eyes from a local slaughterhouse in Vadodara. The butcher removed the eyes immediately after death, and they were kept chilled at a temperature between 0 and 4 degrees Celsius to preserve them. In the lab, we carefully removed the lenses from the eyes. These lenses were then grown for 72 hours in a special, lab-made fluid that mimicked the natural aqueous humour of the eye. This nutrient solution, maintained at a pH of 7.8, was a precise mixture of various salts, minerals, and glucose. To keep the culture sterile and prevent bacterial growth, we added both penicillin and streptomycin to the medium[16].

2.5 Generating the Glucose-induced Cataract Model

In our experiment, we introduced a high concentration of glucose (55mM) to the lenses to trigger the development of cataracts. When the lenses were exposed to this much sugar, they were forced to process it through the sorbitol pathway. This metabolic route caused a buildup of sugar alcohols, or polyols, inside the lens tissue. This accumulation had a damaging effect: it created oxidative stress and effectively dehydrated the lens, pulling moisture out and leaving the tissue dry and vulnerable. These conditions, high sugar, chemical stress, and dehydration, are what ultimately caused the cataracts to form. To test our potential treatment against this process, we dissolved our plant extract in Dimethyl Sulfoxide (DMSO) before applying it[17,18].

2.6 Experimental Groups

Six experimental groups were created, each using one goat eye lens (n=6 total). Group I served as the normal control with a 5.5mM glucose concentration. Group II represented the disease model, exposed to 55mM glucose. Group III received 55mM glucose along with 12 ng/ml enalapril as a reference treatment. Groups IV, V, and VI were treated with 55mM glucose combined with *O. ficus-indica* (L.) Mill. (OFI) pulp extract at three different concentrations: 250 µg/ml, 500 µg/ml, and 1000 µg/ml, respectively.

2.7 Studying an Image's Lens Opacity

To assess the lenses' opacity, we placed their posterior sides on graph paper and incubated them for a full day. Degrees of opacity were scored as follows: 0: No opacity, +: Slight opacity, ++: Diffuse opacity, ++++: Dense, thick opacity[15,16].

2.8 Creating the Lens Homogenate

After a 72-hour incubation, 10% of each lens was homogenised in 0.1 M sodium phosphate buffer (pH 7.4). The homogenate then underwent centrifugation at 10,000 × g for 30 minutes at -4°C. The resulting supernatant was stored at -20°C for further analysis[15].

2.9 Biological Parameter

In the lens supernatant, we measured total protein and catalase enzyme activity. The overall protein content of the lens was estimated using the Lowry method, while catalase activity was evaluated by a UV spectrophotometric assay.

2.10 Statistical Analysis

Statistical analysis was performed using GraphPad Prism version 10.6.0 with a one-way ANOVA. Data from each group of six lenses are expressed as mean ± SEM, and differences were considered statistically significant at $P < 0.05$.

3. Results

3.1 Assessment of Lens Opacities by Photograph

After a 72-hour incubation period, images captured from both standard and experimental lens groups

were analysed using graph paper for visual assessment. When compared to the normal and treatment groups, the disease control group (Group II), which was exposed to 55 mM glucose, exhibited complete lens opacity (Figure 1 and Table 1). By the end of the incubation period, the clouding of the lenses had progressed from the outer regions toward the centre. The lenses treated with the methanolic extract of *O. ficus-indica* (L.) Mill. (OFI) pulp and the standard drug enalapril (12 ng/ml) demonstrated noticeably better transparency. Among the treated groups, lens clarity was highest in Group IV, followed by Group V and Group VI. The observed improvement in lens transparency was directly correlated with the effectiveness of the OD seed extract in preventing cataract formation (Table 1 and Figure 1).

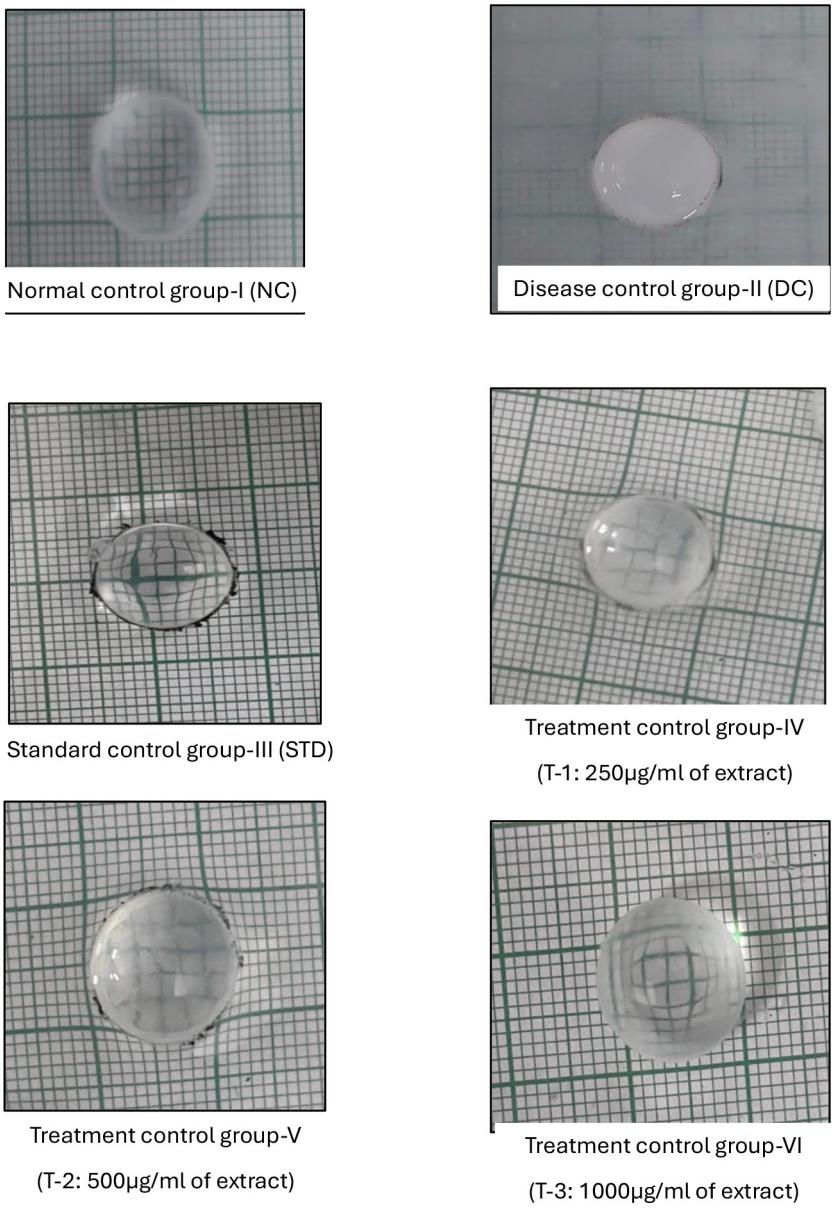


Figure 1. Evaluation of lens opacity through photographic observation after a 72-hour incubation with the pulp extract of *O. ficus-indica* (L.) Mill. (OFI). Group I served as the normal control containing 5.5 mM glucose, while Group II (disease control) included only 55 mM glucose. Group IV was treated with 250 µg/ml of OFI pulp extract along with 55 mM glucose, Group V received 500 µg/ml of the extract with 55 mM glucose, and Group VI was exposed to 1000 µg/ml of the extract combined with 55 mM glucose. Additionally, another treatment group was incubated with 55 mM glucose and 12 ng/ml of the standard drug, Enalapril.

Table 1. Photographic evaluation of lens opacities – degree of opacity (n=6)

Sr. No.	Treatment with *Opuntia ficus-indica* (L.) Mill. (OFI) pulp extract	Degree of opacity
1	Group I – Normal lens – Glucose 5.5 mM	0
2	Group II – Disease lens – Glucose 55 mM	+++++
3	Group III – Standard drug lens – Enalapril 12 ng/ml	0
4	Group IV – Glucose 55 mM + OFI pulp extract extract 250 µg/ml	+++
5	Group V – Glucose 55 mM + OFI pulp extract extract 500 µg/ml	++
6	Group VI – Glucose 55 mM + OFI pulp extract extract 1000 µg/ml	+

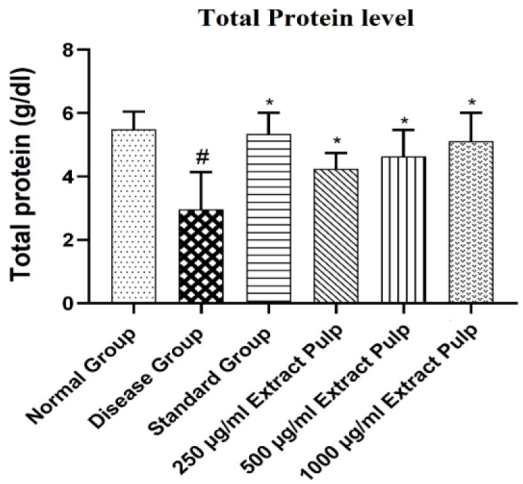


Figure 2. The total protein level in Group II (disease control) showed a significant decrease compared to Group I (normal control). In contrast, treatment with Enalapril at 12 ng/ml (Group III) and *O. ficus-indica* (L.) Mill. (OFI) Pulp extract at different concentrations (Groups IV, V, and VI) resulted in a significant increase in total protein levels relative to Group II. All values are expressed as mean ± SEM (n = 6), with statistical significance set at $P < 0.05$.

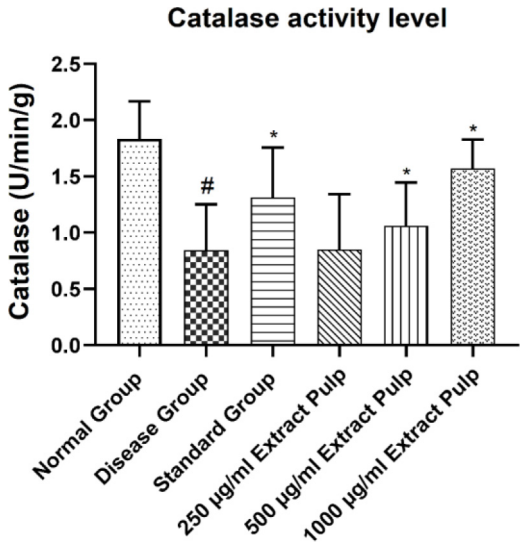


Figure 3. The catalase activity level in Group II (disease control) showed a significant reduction compared to Group I (normal control). In contrast, treatment with Enalapril at 12 ng/ml (Group III) and *O. ficus-indica* (L.) Mill. (OFI) Pulp extract at various concentrations (Groups IV, V, and VI) demonstrated a significant increase in catalase activity relative to Group II. All values are expressed as mean ± SEM (n = 6), with statistical significance considered at $P < 0.05$.

3.2 Total Protein Level

In the lenses from Groups I and III, where cataract development did not occur, protein levels were found to increase (Table 1). In contrast, Group II, which was not treated with *O. ficus-indica* (L.) Mill. (OFI) pulp extract, exhibited dense lens opacity and a marked reduction in protein concentration (Figure 1). When comparing the disease control group with the treatment groups, a significant elevation in total protein content was observed in lenses treated with OFI pulp extract (Figure 2). The total protein level recorded in Group II was 2.96 ± 0.48 g/dl, whereas Groups IV, V, and VI—treated with OFI pulp extract at varying concentrations—showed significantly higher protein levels of 4.25 ± 0.19 g/dl, 4.63 ± 0.34 g/dl, and 5.11 ± 0.36 g/dl, respectively. These findings indicate a considerable restoration of protein content in the treatment groups compared to the glucose-induced cataract group.

3.3 Catalase Activity Level

In Group I lenses, where cataract formation did not occur, catalase activity showed an evident increase

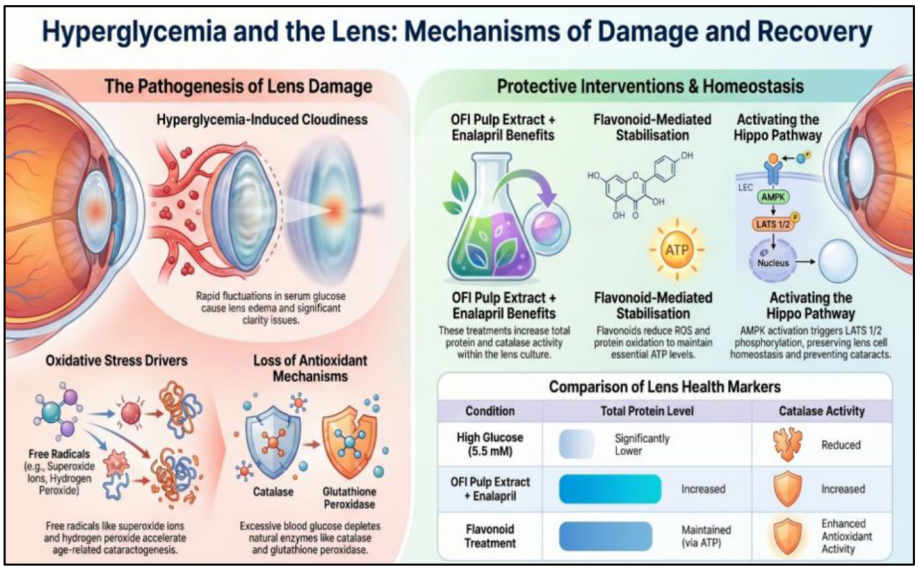


Figure 4. The hyperglycaemia and lens: Mechanisms of damage and recovery.

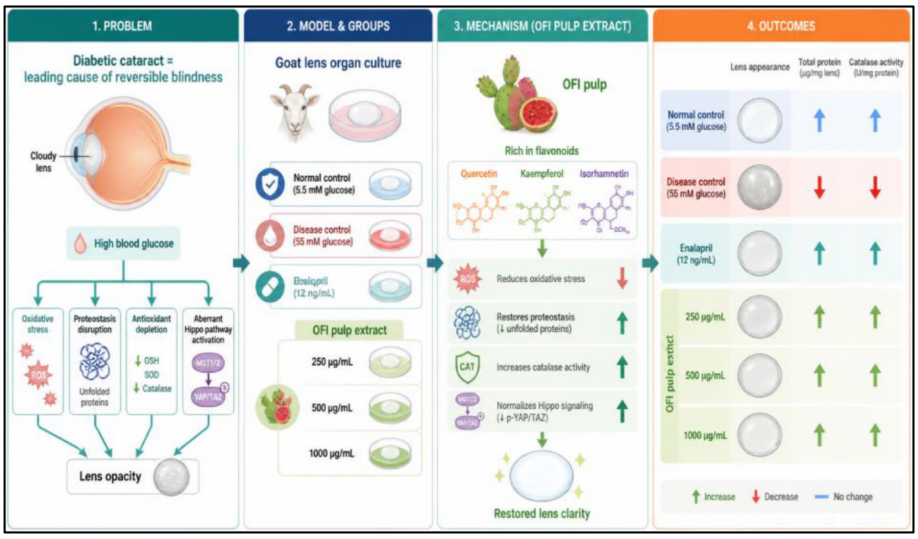


Figure 5. *Opuntia ficus-indica* plant (OFI) has shown promising antioxidant and anti-cataract effects in the goat lens.

(Table 1). In contrast, Group II, which lacked treatment with *3*, exhibited pronounced lens opacity and a significant reduction in catalase activity. When compared with the disease control group, lenses treated with OFI pulp extract demonstrated a marked improvement in catalase activity (Figure 3). The catalase activity in Group II was recorded at 0.84 ± 0.16 U/min/g, whereas Groups IV, V, and VI—treated with increasing concentrations of OFI pulp extract—showed significantly elevated activities of 0.85 ± 0.20, 1.06 ± 0.15, and 1.57 ± 0.10 U/min/g, respectively.

4. Discussion

Several studies have linked hyperglycemia to lens clarity issues. In hyperglycemic patients, fast serum glucose decreases can cause lens cloudiness and oedema. Diabetes may make cataract surgery less effective, despite its improved success. It can cause retinopathy, vitreous haemorrhage, iris neovascularisation, and loss of vision. Lens oxidative stress from free radicals causes age-related cataracts. Besides hydroxyl and hydrogen peroxide, this group comprises lipid hydroperoxides and superoxide anion. Glutathione, vitamin C and E,

carotenoids, and superoxide dismutase may preserve the juvenile lens[19]. It has antioxidant enzymes, including catalase and glutathione peroxidase. Loss of lens antioxidant mechanisms is a major cause of cataractogenesis, a condition caused by excessive blood glucose and free radicals such as superoxide ion (O2-) and hydrogen peroxide. High glucose levels activate antioxidant enzymes because they suggest cellular oxidative stress. This experiment's lens culture had considerably lower lens total protein and catalase activity than Group I's 5.5 mM glucose lens. Enalapril and diverse quantities of *O. ficus-indica* (L.) Mill. (OFI) Pulp extract increased Group B's lens culture's total protein and catalase activity. Antioxidant activity increased in extract-treated groups. To preserve cells and maintain ATP levels, flavonoids reduce ROS, lipid peroxidation, and protein oxidation[20]. Metabolic stabilisation sensitises AMPK. Hippo core kinases activate LATS 1/2 and MST 1/2 phosphorylation when AMPK is active (Figure 4). Phosphorylation and cytoplasmic retention (or degradation) restore the Hippo "on" state. This prevents cataracts by preserving LEC homeostasis.

5. Conclusion

An extract from the pulp of the *O. ficus-indica* plant (OFI) has shown promising antioxidant and anti-cataract effects in goat lenses that were artificially inoculated with glucose to cause diabetic cataract. Research on the possible use of pulp extract from *O. ficus-indica* (L.) Mill. (OFI) to prevent diabetic cataract is ongoing (Figure 5). To further our knowledge in this area, additional research using a variety of *in vivo* animal models is still required.

6. References

1. World Health Organisation. Blindness and vision impairment. Geneva: WHO; 2021.
2. Hashemi H, Pakzad R, Yekta A, Aghamirsalim M, Pakbin M, Ramin S, *et al.* Global and regional prevalence of age-related cataract: a comprehensive systematic review and meta-analysis. Eye (Lond). 2020; 34(8):1357-1370. https://doi.org/10.1038/s41433-020-0806-3 PMID: 32055021; PMCID: PMC7376226.
3. Jiang X, Xu B, Zhai J, Huang S, Cheng H, Ma L, Zhao YE. Global trends in cataract burden: a 30-year epidemiological analysis and prediction of 2050 from the Global Burden of Disease 2021 study. Br J Ophthalmol. 2026; 110(2):139-147. https://doi.org/10.1136/bjo-2025-327776 PMID: 40825656; PMCID: PMC12911648.
4. Bailey RN, Indian RW, Zhang X, Duenas MR, Saaddine JB. Visual impairment and eye care among older adults—five states, 2005. MMWR Morb Mortal Wkly Rep. 2006; 55(49):1321-1325.
5. Thompson J, Lakhani N. Cataracts. Prim Care. 2015; 42(3):409-423. https://doi.org/10.1016/j.pop.2015.05.012 PMID: 26319346.
6. Meyer D, Liebenberg P. Cataract aetiology: a comprehensive review. In: Singh D, editor. Clinical Practice in Small Incision Cataract Surgery. New Delhi: Jaypee Brothers Medical Publishers; 2004. p. 33-84. https://doi.org/10.5005/jp/books/10149_3
7. Sanderson J, Marcantonio JM, Duncan G. A human lens model of cortical cataract: Ca^{2+}-induced protein loss and opacification. Exp Eye Res. 2000; 71(5):547-556.
8. Spector A. Oxidative stress-induced cataract: mechanism of action. FASEB J. 1995; 9(12):1173-1182. https://doi.org/10.1096/fasebj.9.12.7672510 PMID: 7672510.
9. Yu FX, Zhao B, Guan KL. Hippo pathway in organ size control and cancer. Genes Dev. 2015; 29(1):1-17.
10. Noguchi S, Saito A, Nagase T. YAP/TAZ signalling as a molecular link between fibrosis and cancer. Int J Mol Sci. 2018; 19(11):3674. https://doi.org/10.3390/ijms19113674 PMID: 30463366; PMCID: PMC6274979.
11. Mo JS, Meng Z, Kim YC, Park HW, Hansen CG, Kim S, *et al.* Cellular energy stress induces AMPK-mediated regulation of YAP and the Hippo pathway. Nat Cell Biol. 2015; 17(4):500-510. https://doi.org/10.1038/ncb3111 PMID: 25751140; PMCID: PMC4380774.
12. Hilliard A, Mendonca P, Russell TD, Soliman KF. The protective effects of flavonoids in cataract formation through the activation of Nrf2 and the inhibition of MMP-9. Nutrients. 2020; 12(12):3651. https://doi.org/10.3390/nu12123651 PMID: 33261005; PMCID: PMC7759919.
13. Giraldo-Silva L, Ferreira B, Rosa E, Dias AC. *Opuntia ficus-indica* fruit: a systematic review of its phytochemicals and pharmacological activities. Plants (Basel). 2023; 12(3):543. https://doi.org/10.3390/plants12030543 PMID: 36771630; PMCID: PMC9919935.
14. Ali SK, Mahmoud SM, El-Masry SS, Alkhalifah DH, Hozzein WN, Aboel-Ainin MA. Phytochemical screening and characterisation of the antioxidant, anti-proliferative and antibacterial effects of different extracts of *Opuntia ficus-indica* peel. J King Saud Univ Sci. 2022; 34(7):102216. https://doi.org/10.1016/j.jksus.2022.102216
15. Vaghela UP, Vadera D, Vyas B, Rathod A, Chhayani D, Hirpara K, *et al.* Anticataract effects of methanol extract of *Ocimum sanctum* L. leaf on *in vitro* glucose-induced goat

eye lens model. J Nat Remedies. 2025; 25(6):1415-1421. https://doi.org/10.18311/jnr/2025/48625

16. Vaghela UP, Bhalodiya A, Mahajan H, Bhimani D, Patel M, Kirkite S, *et al. Sesamum indicum* L. seed methanol extract inhibits glucose-induced cataract in the isolated goat eye lens. J Nat Remedies. 2025; 25(7):1641-1646. https://doi.org/10.18311/jnr/2025/48626
17. Vaghela UP, Sheth DB, Parekh K, Jani B, Ajudia R, Trivedi R, *et al.* Anticataract effects of *Pergularia daemia* leaf on *in vitro* glucose-induced goat eye lens model. Egypt Pharm J. 2024; 23(1):103-109. https://doi.org/10.4103/epj.epj_144_23
18. Durgapal S, Juyal V, Verma A. *In vitro* antioxidant and *ex vivo* anti-cataract activity of ethanolic extract of *Cineraria maritima*: a traditional plant from Nilgiri Hills. Future J Pharm Sci. 2021; 7(1):105. https://doi.org/10.1186/s43094-021-00258-8
19. Guo Z, Ma X, Zhang RX, Yan H. Oxidative stress, epigenetic regulation and pathological processes of lens epithelial cells underlying diabetic cataract. Adv Ophthalmol Pract Res. 2023; 3(4):180-186. https://doi.org/10.1016/j.aopr.2023.10.001 PMID: 38106550; PMCID: PMC10724013.
20. Tumilaar SG, Hardianto A, Dohi H, Kurnia D. A comprehensive review of free radicals, oxidative stress, and antioxidants: overview, clinical applications, global perspectives, future directions, and mechanisms of antioxidant activity of flavonoid compounds. J Chem. 2024; 2024:5594386. https://doi.org/10.1155/2024/5594386

Author Contribution

UV and KK came up with the idea for the design, the experiments, and the structure of the manuscript. PP, JS, IZ, LV, KG, BV, LP, MV and SA looked at the parameters and wrote the first draft of the manuscript. UV and KK then looked it over and made the final edits. All authors have read and agreed to the published version of the manuscript.

