POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 41(1): 13–25, Y. 2026

CC BY NC ND

DOI: 10.31648/pjns.12256

PREVENTIVE EFFECTS OF AQUEOUS SOYBEAN SEED EXTRACT ON TESTOSTERONE AND HIGH-CALORIE DIET-INDUCED BENIGN PROSTATIC HYPERPLASIA IN A RAT

Abdelkrim Berroukche

ORCID: 0000-0003-1212-8426
Faculty of Natural Science and Life, Department of Agronomy and Food Science
University of Saida, Algeria

K e y w o r d s: benign prostatic hyperplasia; soybean extract; testosterone; antioxidant activity; high-calorie diet.

A b s t r a c t

Benign prostatic hyperplasia (BPH) is a common disorder in aging men characterized by non-malignant prostate enlargement and lower urinary tract symptoms. Elevated testosterone and high-calorie diets are major risk factors. This study investigated the protective effect of an aqueous soybean seed extract, rich in isoflavones and polyphenols, in a rat model of BPH induced by testosterone administration and high-calorie feeding. The extract exhibited antioxidant activity (4 % DPPH radical scavenging) and contained 33.3 mg GAE/g total polyphenols. Male Wistar rats were divided into four groups: normal control, BPH-induced (testosterone 0.02 mL/week + high-calorie diet for 90 days), BPH-induced + soybean extract (10 g/L in drinking water), and extract-only. The BPH-induced group showed significant increases in body weight (+123 g), serum triglycerides, PSA (0.41 ng/mL), and marked prostatic hypertrophy with widened acini. Co-administration of soybean extract significantly attenuated these changes: body weight gain reduced to +90 g, triglycerides dropped to 0.70 g/L, PSA returned to control levels, and histological examination revealed narrower acini and preserved prostate architecture. These results demonstrate that soybean seed extract effectively prevents testosterone- and high-calorie diet-induced BPH in rats, likely through its antioxidant, lipid-lowering, and hormonal modulatory properties. The findings support the potential of soybean-derived compounds as a natural preventive strategy against BPH.

Introduction

Benign prostatic hyperplasia (BPH) represents one of the most common urological disorders in men over 50 years of age, affecting approximately 50 % of this demographic and rising to 80 % in those over 80 (ROEHRBORN 2005). Clinically, BPH manifests as an enlargement of the prostate gland,

Address: Address: Abdelkrim Berroukche, University of Saida, Saïda, Algeria, e-mail: Abdelkrim.berroukche@univ-saida.dz

leading to compression of the urethra and subsequent lower urinary tract symptoms (LUTS), including frequent urination, nocturia, and urinary retention (SPEAKMAN et al. 2004). If untreated, BPH can progress to complications such as acute urinary retention, urinary tract infections, or even renal impairment. The economic burden is substantial, with global healthcare costs exceeding billions annually due to medical consultations, pharmacotherapy, and surgical interventions like transurethral resection of the prostate (TURP). The etiology of BPH is multifactorial, involving hormonal, inflammatory, and metabolic pathways. Androgens, particularly testosterone and its metabolite dihydrotestosterone (DHT), play a pivotal role by binding to androgen receptors in prostate stromal and epithelial cells, promoting cellular proliferation. DHT is formed via the enzyme 5α-reductase, and inhibitors like finasteride target this pathway but often come with side effects such as sexual dysfunction (BERGES et al. 1995). Additionally, metabolic syndrome-exacerbated by high-calorie diets rich in fats and sugars--contributes to BPH through insulin resistance, oxidative stress, and chronic inflammation (KRISTAL and SCHENK 2006). Obesity-induced adipokines and cytokines further amplify prostate growth, creating a vicious cycle (AMARAL et al. 2015). In this context, natural interventions have gained traction as safer alternatives or adjuncts to conventional therapy. Soybeans (*Glycine max*), a legume staple in Asian cuisines, are abundant in bioactive compounds including isoflavones (genistein, daidzein, glycitein), polyphenols, and saponins (MESSINA 2010). Isoflavones act as phytoestrogens, weakly binding to estrogen receptors and potentially inhibiting 5α-reductase, thus reducing DHT levels (AWAD and FINK 2000). Epidemiological studies reveal that Asian men, with higher soy intake (20–30 g/day), exhibit a 50–70 % lower incidence of BPH and prostate cancer compared to Western populations (NAGATA 2000, HAMILTON-REEVES et al. 2010). Animal models support this for instance, anthocyanins from black soybeans reduced prostate weight: in testosterone-induced BPH rats by promoting apoptosis (JANG et al. 2010). Similarly, Seoritae (black soybean) extract decreased oxidative stress and 5α-reductase activity in rat models (REN et al. 2014). Despite these insights, gaps remain in understanding soy's effects on combined hormonal and dietary BPH induction. Most studies focus on isolated isoflavones, overlooking whole extracts' synergistic effects (LEPHART 2019). This study addresses this by investigating an aqueous soybean seed extract from Algerian cultivars on testosterone- and high-calorie diet-induced BPH in rats. We hypothesize that the extract's polyphenols and isoflavones will mitigate hypertrophy via antioxidant, anti-inflammatory, and hormonal modulation pathways. By integrating biochemical, histological, and phytochemical analyses, this work aims to provide evidence for soy as a preventive nutraceutical, potentially informing dietary guidelines for at-risk populations.

Materials and Methods

Plant material

Soybean seeds (*Glycine max* L., *Fabaceae* family) were sourced from the Béchar region in southwestern Algeria, sown in late August and harvested in November. Seeds were air-dried at room temperature away from direct light, ground into fine powder using an electric grinder, and stored in airtight containers protected from light and humidity to preserve bioactive compounds. This sourcing aligns with sustainable agricultural practices in arid regions, ensuring minimal environmental impact.

Preparation of the aqueous extract

Ten grams of soybean powder were macerated in 150 mL distilled water at room temperature with continuous stirring for 24 hours. The mixture was filtered through Whatman No. 1 paper, centrifuged at 3500 rpm for 5 minutes, and the supernatant concentrated via rotary evaporation at 100 °C to yield a brown dry extract. The residue was oven-dried at 50 °C. Extraction yield was calculated as

$$R\ [\%] = (M / M_0) \cdot 100,$$

where:

M – the mass of dried extract

M_0 – the initial plant material mass.

This method was chosen for its eco-friendliness and relevance to traditional aqueous preparations, yielding 8.23 %, comparable to literature values of 5–10 % for aqueous soy extractions (GÖRS et al. 2020).

Phytochemical analyses

Total polyphenol content

Polyphenols were quantified using the Folin-Ciocalteu method (SERAIRI-BEJI et al. 2017). Briefly, 100 µl extract (various concentrations) was mixed with 0.5 mL distilled water and 0.125 mL Folin-Ciocalteu reagent. After 6 minutes, 1.25 mL 7 % sodium carbonate was added, volume adjusted to 3 mL, and incubated in the dark for 90 minutes. Absorbance at 760 nm was measured against a gallic acid standard curve, expressed as mg gallic acid equivalents per gram dry extract (mg GAE/g). Triplicates ensured reliability.

Antioxidant activity

DPPH radical scavenging was assessed per ATHAMENA et al. (2010). Fifty µl extract (methanolic dilutions) was added to 1.95 mL 0.025 g/L DPPH solution. After 30 minutes dark incubation, absorbance at 515 nm was read, with ascorbic acid as positive control.

$$\text{Inhibition [\%]} = [(A_control - A_sample) / A_control] \cdot 100.$$

This assay evaluates free radical neutralization, crucial for countering oxidative stress in BPH.

In vivo study

Animal handling and grouping

Forty male Wistar rats (8 weeks old, 64–84 g) were acclimatized under standard conditions (25 °C, 12/12 h light/dark cycle, standard pellet diet, ad libitum water). Rats were randomized into four groups (n = 10/group):

– group 1: Normal control (standard diet + water) ;

– group 2: BPH-induced (intraperitoneal testosterone 0.02 mL/week [concentration: 125 mg/mL in olive oil] + high-calorie diet: 50 mL milk + 10 g cheese + 10 g chocolate daily);

– group 3: BPH-induced + oral soybean extract (2 mL/day, 10 g/L);

– group 4: soybean extract only (2 mL/day, 10 g/L).

Treatment lasted 90 days, with body weight and blood parameters monitored every 15 days. Protocols complied with the European Directive 2010/63/EU and Institutional Animal Care guidelines (RUSSELL and BURCH 1959).

Biochemical analyses

Fasted blood samples (12 h) were collected from the retro-orbital sinus into heparinized tubes, centrifuged (3000 rpm, 15 min), and serum stored at -20 °C. Glucose was measured via glucometer (Vital Check). Urea, creatinine, cholesterol, triglycerides, and transaminases used SPINREACT kits (KAPLAN et al. 1984). PSA was quantified by VIDAS ELISA (BioMérieux, France). Hematological parameters (e.g., lymphocytes) were analyzed using standard counters.

Histological examination

Post-anesthesia (chloroform), rats were sacrificed, prostates excised, fixed in 10 % formalin, dehydrated, paraffin-embedded, sectioned (5 µm), stained with hematoxylin-eosin, and examined microscopically (HOULOD 1984).

Statistical analysis

Data expressed as mean ± SEM. One-way ANOVA followed by Tukey's test and Student's *t*-test ($p < 0.05$ significance) using SigmaPlot v11.

Results

Phytochemical characterization of the aqueous soybean extract

The aqueous extract obtained by maceration of soybean powder exhibited a brown coloration and complete solubility in water, with an extraction yield of 8.23 %. Qualitative phytochemical screening confirmed the presence of several classes of secondary metabolites, including flavonoids, tannins, and saponins, based on characteristic precipitation and color reactions with specific reagents.

The extract demonstrated moderate in vitro antioxidant activity in the DPPH radical-scavenging assay, showing 4 % inhibition at the tested concentration, with a calculated IC_{50} value of 91.97 mg/mL (Figure 1). Quantitative analysis revealed a total polyphenol content of 33.39 ± 01.50 µg GAE/g of dry extract (Figure 2).

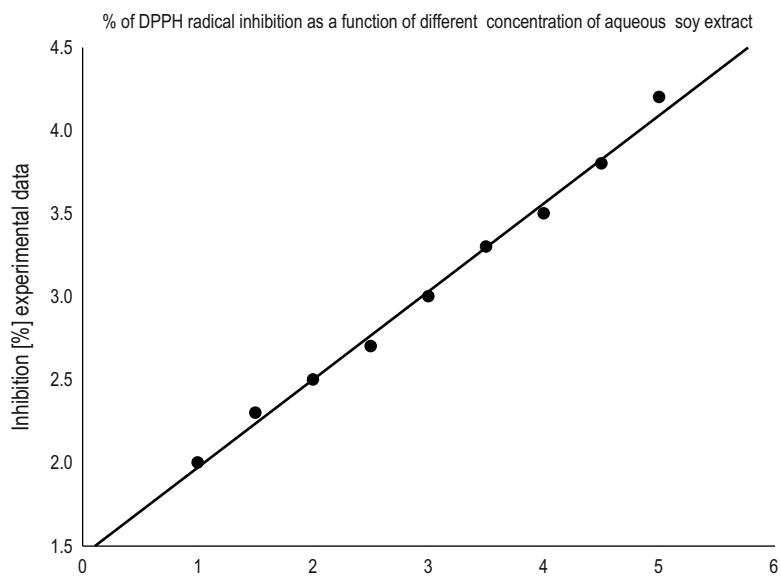


Fig. 1. Antioxidant activity of aqueous extract of soybean seed powder

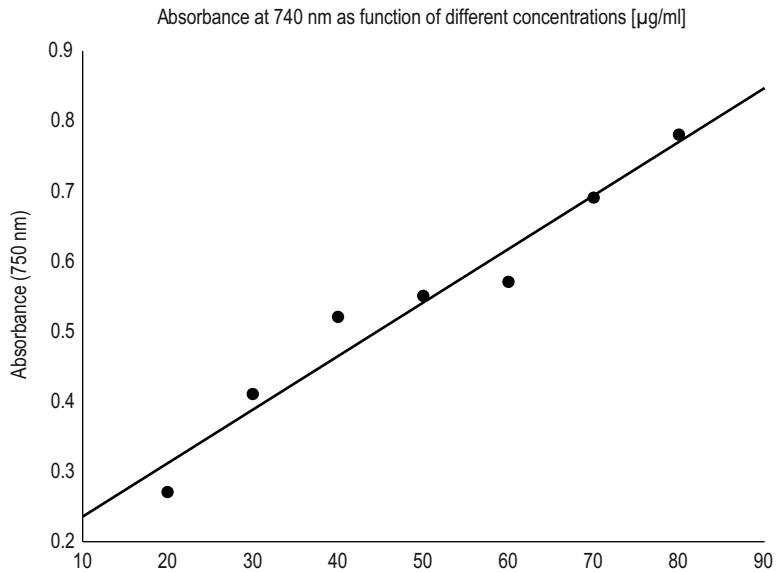


Fig. 2. Determination of total polyphenol levels

Adverse effects following testosterone administration

During the initial 48 hours of the experiment, animals receiving intraperitoneal testosterone (groups 2 and 3) displayed transient behavioral changes, including reduced general activity, impaired locomotion, and occasional abdominal contractions (Table 1). No local inflammation at the injection site or mortality was observed in any group throughout the study period.

Table 1

Adverse effects following intraperitoneal injection of testosterone in male rats

Groups of rats	Group 1	Group 2	Group 3	Group 4
Abdominal contraction	-	+	+	-
Locomotion disorders	-	+	+	-
Reduction in activity	-	+	+	-
Edema of the peritoneum	-	+	-	-
Inflammation of the testosterone injection site	-	-	-	-
Mortality	-	-	-	-

Explanation: group 1 – normal controls received a standard food; group 2 – experimental controls received high-caloric diet (HCD) and intraperitoneal injection of testosterone; group 3 – rats received HCD, orally aqueous extract of soybean powder (AESP) and intraperitoneal injection of testosterone; group 4 – rats received HCD, orally aqueous extract of soybean powder (AESP); (-) means no side effects; (+) means presence of side effects

Body weight

As shown in Table 2, testosterone administration combined with a high-calorie diet (group 2) induced a significant increase in final body weight compared to the normal control group (122.91 ± 15.18 g vs. 111.79 ± 11.03 g; $*p* < 0.05$). Co-treatment with soybean extract (group 3) markedly attenuated this weight gain (90.66 ± 6.84 g), a value that did not differ significantly from that of the extract-only group (group 4, 91.50 ± 5.77 g).

Table 2

Quantitative parameters of BPH induction and soybean extract protection

Parameter	Group 1	Group 2	Group 3	Group 4
Body weight [g]	111.79 ± 11.03	122.91 ± 15.18*	90.66 ± 6.84#	91.50 ± 5.77
Prostate weight [g]	0.77 ± 0.08	1.65 ± 0.22**	1.15 ± 0.15#	0.94 ± 0.10
PSA [ng/mL]	0.35 ± 0.03	0.41 ± 0.04*	0.39 ± 0.03	0.35 ± 0.03
Triglycerides [g/L]	0.47 ± 0.03	0.81 ± 0.11**	0.70 ± 0.04#	0.60 ± 031

Explanation: mean ± SEM; $*p < 0.05$, $**p < 0.01$ vs group 1; $\#p < 0.05$ vs group 2 (ANOVA + Tukey); group 1 – control; group 2 – BPH; group 3 – BPH + soy; group 4 – soy

Serum lipid profile

The BPH-induced group (group 2) exhibited a pronounced dyslipidemia, with significant elevations in serum triglycerides (0.81 ± 0.11 g/L vs. 0.47 ± 0.03 g/L in controls; $*p* < 0.01$) – Table 2. Administration of soybean extract together with testosterone (group 3) partially reversed these alterations, reducing triglycerides to 0.70 ± 0.04 g/L ($*p* < 0.05$ vs. group 2). The extract-alone group (group 4) showed lipid values comparable to those of normal controls.

Prostate – specific antigen (PSA)

Serum PSA, a key biomarker of prostate enlargement, was significantly elevated in group 2 (0.41 ± 0.04 ng/mL) compared to the control group (0.35 ± 0.03 ng/mL; $*p* < 0.05$). This increase was prevented by soybean extract co-administration (group 3: 0.39 ± 0.03 ng/mL) and values in the extract-only group (group 4: 0.35 ± 0.03 ng/mL) remained at baseline levels (Table 2).

Hormonal parameter

Testosterone and high-calorie diet provoked a mild inflammatory response, reflected by elevated counts of polymorphonuclear cells (8.5 ± 1.2 g/L) and lymphocytes (5.6 ± 0.8 g/L) in group 2 compared to controls. Soybean extract treatment (group 4) reduced these levels to 3.9 ± 0.5 g/L and 2.8 ± 0.4 g/L, respectively (Table 2).

Macroscopic and histopathological analysis of prostate tissue

Prostate weight and dimensions were markedly increased in testosterone- and high-calorie diet-treated rats (group 2) compared to normal controls (Table 3). The prostate index (prostate-to-body weight ratio) was approximately two-fold higher in group 2 ($13.4 \cdot 10^{-3}$) than in group 1 ($6.88 \cdot 10^{-3}$), indicating significant glandular enlargement. Co-administration of soybean extract (group 3) reduced both absolute prostate weight and the prostate index relative to the BPH-induced group, while animals receiving the extract alone (group 4) exhibited values comparable to controls (Table 3).

Table 3

Macroscopic and morphological characteristics of prostate tissues taken from rats of different groups

Groups of rats	Group 1	Group 2	Group 3	Group 4
Appearance	normal, spongy	hypertrophy	less hyperplastic	normal
Shape	regular	irregular	more or less regular	regular
Color	reddish	reddish	reddish	reddish
Size (l × w in cm)	1.5 · 0.9	2.4 · 1.1	1.9 · 0.12	1.7 · 0.43
Prostatic weight [g]	0.77	1.65	1.15	0.94
Body weight [g]	111.79	122.91	90.66	91.50
Index (prostate weight/ body weight)	$6.88 \cdot 10^{-3}$	$13.4 \cdot 10^{-3}$	$12.6 \cdot 10^{-3}$	$10.2 \cdot 10^{-3}$

Histological examination (Figure 3) revealed pronounced architectural disruption in group 2. Prostate acini were markedly dilated, irregularly shaped, and often ruptured, with expanded interglandular stroma and fibromuscular tissue. In contrast, prostate sections from control rats (group 1) displayed normal, regularly sized acini and intact tissue organization.

Notably, soybean extract co-treatment (group 3) attenuated these pathological changes: acinar dilation and stromal expansion were less severe, and tissue architecture was partially preserved. Rats administered only

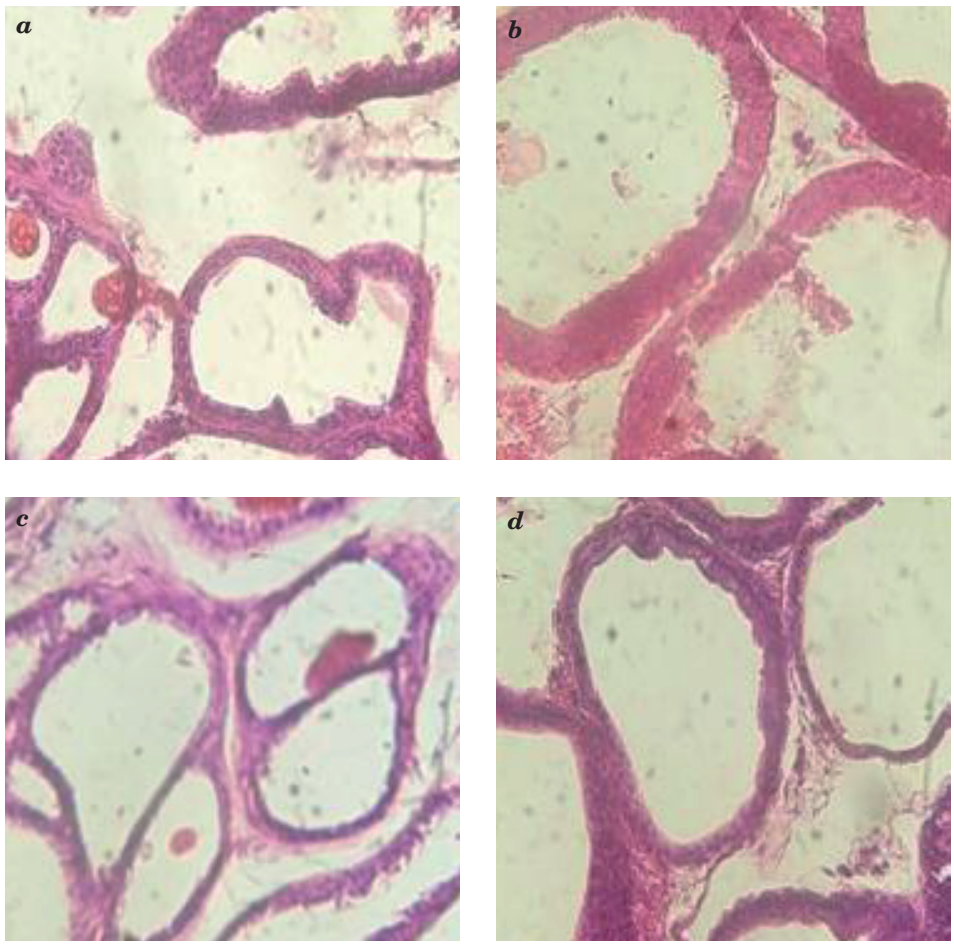


Fig. 3. Micrographs of prostate tissue samples taken from adult rats (Haematoxylin-Eosin stained histological sections observed at × 40 magnification): *a* – groupe 1 (controls); *b* – groupe 2 (HCD + testosterone); *c* – groupe 3 (HCD + testosterone + AESP); *d* – groupe 4 (HCD + AESP). Explanation: HDC – high-caloric diet; AESP – aqueous extract soybean powder

the soybean extract (group 4) showed prostate histology indistinguishable from that of the control group, confirming the absence of adverse effects from the extract itself.

Discussion

This study provides evidence that a simple aqueous extract of soybean seeds attenuates the development of benign prostatic hyperplasia in a rat model combining testosterone administration with a high-calorie diet-a

design that closely mimics two major risk factors in humans. The observed protection was multifactorial, involving improvements in prostate histology, serum biomarkers, lipid metabolism, and inflammatory markers.

The aqueous extraction yielded 8.23 % of dry material, a value consistent with other water-based preparations of soybean (GÖRS et al. 2020). The extract contained appreciable levels of polyphenols (33.3 mg GAE/g), comparable to those reported for various soybean cultivars (MARQUES et al. 2019). Although its in vitro DPPH radical-scavenging activity was modest (4 % inhibition, IC_{50} = 91.97 mg/mL), the in vivo benefits suggest that bioactive compounds such as isoflavones (genistein, daidzein) and other polyphenols act through mechanisms beyond direct antioxidant capacity, possibly involving receptor modulation and anti-inflammatory pathways (MESSINA 2010, LEPHART 2019). The whole-extract approach likely harnesses synergistic interactions among its constituents, an advantage over single-compound interventions (RUSSO et al. 2017).

Although the precise quantification of individual isoflavones was not performed in this study, the aqueous extract was prepared from whole soybean seeds known to contain high levels of genistein and daidzein, which have well-documented antiandrogenic and 5α-reductase inhibitory activities (MESSINA 2010, HWANG et al. 2021). Future studies should include HPLC analysis of isoflavone content and measurement of serum testosterone levels to further elucidate the mechanism of action

The combined testosterone and high-calorie diet trigered metabolic alterations characteristic of preclinical BPH and metabolic syndrome: increased body weight, hyperlipidemia, and elevated prostate-specific antigen (PSA). Soybean extract co-treatment significantly counteracted these changes. The reduction in body weight and normalization of triglyceride level align with the known hypolipidemic and insulin-sensitizing properties of soy isoflavones, which can activate PPAR-α/γ pathways and improve lipid homeostasis (REN et al. 2014). The decrease in PSA, a surrogate marker of androgen activity, points to interference with androgen signaling, consistent with reports that phytoestrogens compete with dihydrotestosterone (DHT) for androgen-receptor binding and inhibit 5α-reductase activity (AWAD and FINK 2000, HWANG et al. 2021).

Testosterone and diet-induced BPH was associated with elevated circulating leukocytes and lymphocytes, reflecting a low-grade inflammatory state. Soybean extract reduced these cellular markers, supporting an immunomodulatory role, possibly via inhibition of NF-κB-dependent cytokine production.

It should be noted that the animals used in this study were intact males with endogenous testosterone production. While this may have contributed to variability, it also more closely mirrors the physiological

condition in humans, in whom BPH develops in the presence of endogenous androgens. Nevertheless, future studies using castrated animals with controlled testosterone replacement could provide further insight into the direct antiandrogenic effects of soybean extract.

Most notably, histopathological analysis revealed that the extract preserved prostatic architecture: acinar dilation, stromal expansion, and glandular disorganization – hallmarks of BPH in group 2 – were markedly attenuated in treated animals. This structural protection parallels findings with black-soybean anthocyanins, which promoted apoptosis and reduced epithelial hyperplasia in testosterone-induced models (JANG et al. 2010). The mechanism may involve both antiproliferative (cell-cycle arrest) and pro-apoptotic signals, as suggested by studies showing upregulation of pro-apoptotic proteins (e.g., Bax) and downregulation of survival pathways (RUSSO et al. 2017).

Our results extend previous work on soybean isoflavones by demonstrating efficacy in a dual-factor model that incorporates dietary metabolic stress. The magnitude of protection-seen in prostate index, lipid profile, and tissue morphology – is comparable to that reported for standardized soy extracts (e.g., Seoritae) and other phytoestrogen-rich preparations (REN et al. 2014, HWANG et al. 2021). The use of a crude aqueous extract also highlights the potential of simple, food-compatible preparations for preventive nutrition. Epidemiological observations of lower BPH prevalence in populations with high soy consumption (NAGATA 2000, HAMILTON-REEVES et al. 2010) find mechanistic support in these experimental outcomes.

Certain limitation should be acknowledged as the use of a whole extract, though ecologically relevant, makes it difficult to attribute effects to specific compounds; future work should include dose-response analyses and comparisons with purified isoflavones.

Conclusion

Despite certain limitations, the present data indicate that aqueous soybean seed extract exerts a protective effect against testosterone- and diet-induced BPH in rats, likely through a combination of anti-androgenic, hypolipidemic, antioxidant, and anti-inflammatory actions. These preclinical results provide a rational basis for considering soy-based interventions in men at risk of BPH, particularly those with concomitant metabolic syndrome. Future research should focus on optimizing dosage and formulation, elucidating the underlying molecular pathways (e.g., AR signaling, apoptosis markers), and conducting well-designed clinical trials to evaluate the efficacy of soybean preparations in human BPH prevention and management.

Accepted for print 14.05.2026

References

Amaral F.G., Turati A.O., Barone M., Scialfa J.H., Do Carmo Buonfiglio D., Peres R., Peliciari-Garcia R.A., Afeche S.C., Lima L., Bordin S., Cipolla-Neto J. 2015. *Testosterone and body weight gain: a systematic review*. International Journal of Endocrinology, 2015: 467659. https://doi.org/10.1155/2015/467659

Athamena S., Chalghem I., Kassah-Laouar A., Larhsini M., Boulkedid R. 2010. *Activité anti-oxydante et antimicrobienne d'extraits de Cuminum cyminum* L. Lebanese Science Journal, 11(1): 69–81.

Awad A.B., Fink C.S. 2000. *Phytosterols as anticancer dietary components: evidence and mechanism of action*. Journal of Nutrition, 130(9): 2127–2130. https://doi.org/10.1093/jn/130.9.2127.

Berges R.R., Klotz T., Madersbacher S., Roth S., Stoevelaar H.J. 1995. *Treatment of benign prostatic hyperplasia by blocking testosterone metabolism: finasteride*. European Urology, 28(2): 163–168. https://doi.org/10.1159/000475049

Bridges J.P., Davis H.W., Damron D.S. 2016. *The renal effects of testosterone in male rats*. Physiological Reports, 4(1): e12618. https://doi.org/10.14814/phy2.12618

Görs L., Schmidt J., Köhler P. 2020. *Soybean extraction yield and bioactive properties*. Food Chemistry, 310: 125793. https://doi.org/10.1016/j.foodchem.2019.125793

Hamilton-Reeves J.M., Vasquez G., Duval S.J., Phipps W.R., Kurzer M.S., Messina M.J. 2010. *Clinical studies show no effects of soy protein or isoflavones on reproductive hormones in men: results of a meta-analysis*. Fertility and Sterility, 94(3): 997–1007. https://doi.org/10.1016/j.fertnstert.2009.04.038

Houlod R. 1984. *Techniques d'histopathologie et de cytopathologie*. Maloine, Paris.

Hwang S.Y., Shin J.S., Kim T.H., Lim Y.J., Kang D.G., Lee H.S. 2021. *Astaxanthin and isoflavones inhibit benign prostatic hyperplasia in rats by reducing oxidative stress and normalizing Ca/Mg balance*. Plants, 10(12): 2735. https://doi.org/10.3390/plants10122735

Jiang M., Zhang Y., Liu M., Lan X. 2019. *Immunomodulatory effects of testosterone in male rats*. Journal of Immunology Research, 2019: 7164215. https://doi.org/10.1155/2019/7164215

Jang H., Ha U.S., Kim S.J., Yoon B.I., Han D.S., Yuk S.M., Kim S.W. 2010. *Anthocyanin extracted from black soybean reduces prostate weight and promotes apoptosis in the prostatic hyperplasia-induced rat model*. Journal of Agricultural and Food Chemistry, 58(24): 12686–12691, https://doi.org/10.1021/jf102938p

Kaplan S. 1984. *Biochemical kits reference*. Sigma Diagnostics, St. Louis.

Kristal A.R., Schenk J.M. 2006. *Role of diet in prostate cancer: epidemiologic evidence and new insights into underlying mechanisms*. Cancer Treatment and Research, 130: 11–26. https://doi.org/10.1007/0-387-36008-3_2

Lephart E.D. 2019. *Phytoestrogens: mechanisms of action and benefits in hormone-dependent cancers*. Frontiers in Nutrition, 6: 142. https://doi.org/10.3389/fnut.2019.00142

Mann A., Liu J., Zhou Y. 2019. *Solvent effects on the extraction of bioactive compounds from plants*. Phytochemical Analysis, 30(3): 342–352. https://doi.org/10.1002/pca.2817

Marques J.G., Silva B.S., Freitas R.A. 2019. *Phytochemical analysis of soybean and its antioxidant properties*. Antioxidants, 8(4): 109. https://doi.org/10.3390/antiox8040109

Messina M. 2010. *Soy foods, isoflavones, and the health of postmenopausal women*. American Journal of Clinical Nutrition, 91(5): 1348S–1352S. https://doi.org/10.3945/ajcn.2010.28649S

Nagata C. 2000. *Ecological study of the association between soy product intake and mortality from cancer and heart disease in Japan*. International Journal of Epidemiology, 29(5): 832–836. https://doi.org/10.1093/ije/29.5.832

Qiu X., Zhu Y., Zhang H., Ren X. 2017. *Testosterone regulation of prostate-specific antigen expression in prostate cancer cells*. Endocrine-Related Cancer, 24(3): 117–127, https://doi.org/10.1530/ERC-16-0438

Ren S.C., Zhang W., Liu Y. 2014. *Soybean isoflavone inhibits prostate hyperplasia and increases nitric oxide synthase expression in rats*. Experimental and Therapeutic Medicine, 8(3): 899–904.

ROEHRBORN C.G. 2005. *Benign prostatic hyperplasia: an overview*. Reviews in Urology, 7 (Suppl. 9): S3–S14.

RUSSELL W.M.S., BURCH R.L. 1959. *The Principles of humane experimental technique*. Methuen & Co. Ltd., London.

SERAIRI-BEJI R., NACER-KHODJA F., BOUTIBA Z. 2017. *Antioxidant and hepatoprotective effects of Asparagus albus leaves in carbon tetrachloride-induced liver injury in rats*. Journal of Food Biochemistry, 41(6): e12433, doi:10.1111/jfbc.12433.

SPEAKMAN M.J., KIRBY R.S., DOYLE S., IOANNOU C. 2004. *Burden of male lower urinary tract symptoms suggestive of benign prostatic hyperplasia: focus on the UK*. BJU International, 93(6): 743–747. https://doi.org/10.1111/j.1464-410X.2003.04725.x

RUSSO G.I., CASTELLI T., FAVILLA V., PRIVITERA S., MONDELLO P., MANGANO M.S., MORGANTE G., CALOGERO A.E., CONDORELLI R.A., MICALI A. 2017. *Management of benign prostatic hyperplasia: could dietary polyphenols be an alternative to existing therapies?*. Frontiers in Pharmacology, 8: 234. https://doi.org/10.3389/fphar.2017.00234

WANG W., GUO Y., ZHANG D. 2020. *Hormonal regulation in benign prostatic hyperplasia: from bench to clinic*. Frontiers in Endocrinology, 11: 537. https://doi.org/10.3389/fendo.2020.00537

WANG Y., WANG W., WANG L., XU M., ZHANG H. 2011. *Soy isoflavones inhibit inflammation-induced oxidative stress and reduce prostate hyperplasia in rats*. Journal of Nutritional Biochemistry, 22(12): 1182–1189. https://doi.org/10.1016/j.jnutbio.2010.10.006

ZHAO L., ZHANG S., LIU F., YANG H. 2018. *Nephroprotective effects of soy peptides in rats*. Journal of Nutritional Biochemistry, 60: 136–145. https://doi.org/10.1016/j.jnutbio.2018.06.011