serve as a feed supplement.[19] It represents one of the non-traditional plant protein sources. However, several trials have demonstrated growth retardation in animals consuming diets supplemented with jojoba meal[36] due to the presence of simmondsin and simmondsin-2-ferulate.[37] These compounds were considered toxic probably after metabolism by gut microorganisms.[38] However, elimination of jojoba seed meal anti-nutritional factors could be done by different methods, including solvent extraction, heat, chemical treatment, and microbial fermentation.[39]

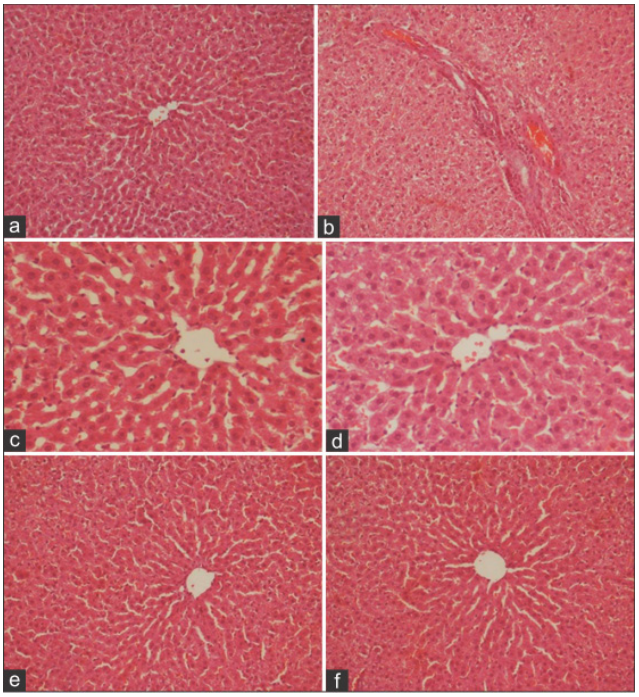

Figure 3: A photomicrograph of liver section of (a) control rat showing normal structure of hepatic lobule, central vein, and blood sinusoid(s); (b) rat fed FB_1-contaminated diet showing vacuolar degeneration, hepatocellular necrosis, and congestion of blood sinusoids which are surrounded by aggregation of inflammatory cells, proliferation and dilation of bile duct, and signs of fibrosis; (c) rat treated with JELD showing normal hepatocytes architecture and dilation of sinusoid; (d) rat treated with JEHD showing no pathological changes; (e) rat fed FB_1-contaminated diet and treated with JELD showing marked improvement in histological features of hepatocyte tissue with minimal vacuolar degeneration still present; and (f) rat fed FB_1-contaminated diet and treated with JEHD showing histological features resembling that of normal hepatocytes (a, e, f: HE, ×200; b, c, d: HE, ×400). FB_1: fumonisin B_1; JELD: low dose of jojoba seed extract; JEHD: high dose of jojoba seed extract

Table 2: Effect of jojoba extract on serum cytokines and NO in rats fed FB_1-contaminated diet

Groups parameter	CEA (ng/mL)	TNF-α (ng/L)	IL-1α (ng/mL)	NO (μmol/L)
Control	1.99 ± 0.42[a]	43.2 ± 3.53[a]	0.68 ± 0.02[a]	23.72 ± 2.11[a]
FB_1	8.66 ± 1.43[b]	87.32 ± 3.21[b]	5.12 ± 0.87[b]	57.28 ± 3.21[b]
JELD	1.92 ± 0.72[a]	43.32 ± 1.98[a]	0.81 ± 0.04[c]	26.72 ± 1.73[c]
JEHD	1.98 ± 0.62[a]	45.37 ± 3.25[a]	0.81 ± 0.06[c]	29.83 ± 1.83[d]
FB_1 + JELD	3.53 ± 0.43[c]	62.11 ± 3.47[c]	1.55 ± 0.12[d]	28.94 ± 1.29[d]
FB_1 + JEHD	2.14 ± 0.22[a]	42.18 ± 2.33[a]	1.22 ± 0.07[d]	32.93 ± 2.94[e]

Within each row means superscript with different letters are significantly different at $P \leq 0.05$. FB_1: fumonisin B_1; JELD: low dose of jojoba seed extract; JEHD: high dose of jojoba seed extract; CEA: carcinoembryonic antigen; TNF-α: tumor necrosis factor-alpha; IL-1α: interleukin 1 alpha; NO: nitric oxide

In this study, we evaluated the ability of ethanol extract of jojoba seeds to protect the liver of laboratory animals from the toxic effects of FB_1. The tested animals were given an extreme FB_1 challenge to ensure induction of severe response. The selected doses of FB_1 and jojoba seed extract were based on our previous work and others,[8,40] respectively. The current results indicated that the ethanol extract of jojoba seeds is rich in total phenolics, crude protein, phytic acid, and simmondsin. These results were in accordance with those reported previously.[19,41-43] Moreover, Shrestha *et al*.[23] reported that jojoba protein consisted mainly of albumins and globulins. The decrease in body weight gain and food intake reported in this study in the group fed FB_1-contaminated diet indicated the presence of adverse effects and toxicity in rats caused by ingestion of FB_1. This decrease may indicate protein catabolism, thereby contributing to the observed kidney injury.[8,9,44,45] Similar decrease in body weight gain and food intake had been reported in rats,[9,44] swine,[45] horses,[46] broiler,[47] and Turkey poults[48,49] fed fumonisin. Previously, Abdel-Wahhab *et al*.[8] and El-Nekeety *et al*.[9] stated that administration of FB_1 to rats enhanced lipid peroxidation which presumably resulted from free-radical-mediated toxicity. Stockmann-Juvala *et al*.[50] found that FB_1 evoked oxidative stress, which may contribute at least in part to FB_1-induced toxicity and carcinogenicity.

The elevation of ALT, AST, ALP, triglycerides, and cholesterol in the group fed FB_1-contaminated diet indicated necrosis or hepatocellular injury.[9] The results of this study also revealed that treatment with FB_1 resulted in a significant increase in serum CEA, TNF-α, IL-1α, and NO suggesting that FB_1 can induce hepatotoxicity in rats. Similar results suggested earlier indicated that TNF-α, IL-1α, and NO were produced by macrophages, and they played a vital role in tumor conditions.[51] Moreover, TNF-α is an essential factor in tumor promotion[52] and is a key factor that regulates the production of other

Table 3: Effect of jojoba extract on antioxidants and lipid peroxidation in liver of rats fed FB_1-contaminated diet

Groups parameter	Control	FB_1	JELD	JEHD	JELD + FB_1	JEHD + FB_1
MDA (mol/mg protein)	66.85 ± 2.37[a]	115.36 ± 3.44[b]	67.26 ± 2.73[a]	68.23 ± 3.16[a]	87.74 ± 3.19[c]	85.91 ± 3.02[c]
SOD (u/mg protein)	331.43 ± 8.65[a]	166.74 ± 7.34[b]	352.33 ± 3.46[c]	348.93 ± 5.88[c]	258.33 ± 6.72[d]	277.76 ± 4.27[e]
TAC (mol/g protein)	82.25 ± 4.28[a]	123.32 ± 6.43[b]	92.28 ± 4.34[c]	97.28 ± 6.22[c]	95.28 ± 7.22[c]	104.33 ± 2.75[d]

Within each row means superscript with different letters are significantly different at $P \leq 0.05$. FB_1: fumonisin B_1; JELD: low dose of jojoba seed extract; JEHD: high dose of jojoba seed extract; MDA: malondialdehyde; SOD: super oxide dismutase; TAC: total antioxidant capacity