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行政院農業委員會農糧署98年度科技計畫研究報告

計畫名稱： 荷葉萃取物開發為降低肝臟脂肪及不易形成體脂肪之健康食品 (第1年/全程1年)

(英文名稱) Study and application of Nelumbo nucifera leaf extract to attenuate hepatic lipid and bodily fat accumulation

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計畫主持人： 王朝鐘
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執行機關： 私立中山醫學大學

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行政院農業委員會農糧署

九十八年度科技計劃研究報告

荷葉萃取物開發為降低肝臟脂肪及不易形成體脂肪之健康食品

Study and application of *Nelumbo nucifera* leaf extract to attenuate hepatic lipid and bodily fat accumulation

98農科-5.4.1-糧-Z9

計劃主持人：王 朝 鐘

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中文摘要

隨著生活水準的提高，飲食習慣也有所不同，高精緻化的要求與速食業的普及，使得人們在罹患與肥胖相關的慢性病，有逐年增高的趨勢，若能發展一無副作用的天然食品，且具有降低血脂，抑制脂肪肝行程及減少體內體脂肪之功效，將有助於達到預防許多慢性疾病發生之目的。荷葉盛產於本省中南部，易栽培且食用上並無副作用，並含有多種酚酸成分，具有抗氧化、防癌及抑制高血脂之作用，先前的研究我們已證實荷葉萃取物可以抑制兔子血管病變，降低脂肪肝及減少血脂之作用，本研究進一步證實荷葉萃取物具有抑制體脂肪的形成及促進體脂肪利用，明顯的降低高血脂食物誘導之體重增加，因此本研究可以發展荷葉萃取物為(1)高脂糧餵食之脂肪肝護肝作用；及(2)不易形成體脂肪之健康食品。

英文摘要

Obesity is a disorder of energy imbalance and the most prevalent nutritional diseases in developed countries. Besides, obesity is also associated with health problems such as type 2 DM, hypertension, hyperlipidaemia, cardiovascular diseases and cancers. *Nelumbo nucifera* Gaertn is widespread in the middle and southern of Taiwan. *Nelumbo nucifera* Gaertn leaf extract (NLE) has been identified a lot of benefit about anti-oxidant and reduced risk of cardiovascular disease. Our study has demonstrated NLE could attenuate hepatic lipid accumulation and reduce visceral adipose tissues elevation by a high-fat diet. The results suggest that NLE may be an effective health food for the treatment of obesity and fatty liver.

前言

肥胖的副作用

在現今的社會，人們的飲食愈來愈多元化與精緻化，尤其是油炸類的美食最令人愛不釋手，然而這些高熱量的食物在長時間的攝取下，會造成體內能量代謝失衡，導致過多的脂肪堆積於體內，也就是所謂的肥胖症。以前大家只是把它當成是種體態上的不美觀，甚至在更早以前人們會把它當成是種福氣的象徵，但是事實上應嚴肅的將它視為一種慢性疾病。日前世界衛生組織一個專案小組公佈一項調查，發現目前全球需要減肥的人超過十七億，肥胖人口數甚至超越了飢餓人口，肥胖儼然成為廿一世紀最重大的流行病(1)，但或許正因為肥胖和現代生活型態的關係太密切，一般人對這個問題似乎反而沒那麼在意。肥胖帶來的疾病和死因 由世界衛生組織的調查推估，全球每四個人當中就有一人太胖，而肥胖之所以可怕，並不止於它本身的問題，而是由肥胖帶來的疾病和死因。一直以來，人們認為肥胖帶來的最大威脅是糖尿病和心臟病，而且也會因為太胖而導致高血壓。但最新的研究顯示，肥胖的問題還不僅如此，脂肪細胞會影響人體胰島素的製造和使用，當胰島素的功能被破壞，會使得不必要的脂肪流入血液內。 換言之，人體的胰臟必須產生更多的胰島素和其他蛋白質，否則將無法糾正這種異常的現象。 一旦胰島素增加太快，可能對動脈內壁造成不利的影響，進而造成血管阻塞(2)。 脂肪細胞所帶來的各種蛋白質，以及其他因肥胖而引起的激素，有可能導致多種癌症發生，包括：乳癌、子宮癌、結腸癌、腎癌、食道癌、胰癌和膽囊癌等(3)。

肝臟是人體最大也是功能最複雜的器官，尤其是在代謝的這個部

份，幾乎包辦所有營養物質的分解與生合成。而正常的肝臟脂肪佔肝臟重量的5%，其中有一半為中性脂肪(三酸甘油酯, triglyceride)與脂肪酸，其餘少量為膽固醇、磷脂質等。然而當肝內的脂肪含量(主要是三酸甘油酯) 超過肝總重的5% 以上，或是肝組織切片超過10% 以上的肝細胞有脂肪空泡堆積的情形出現，就將它稱之為脂肪肝。肝病基金會曾對9000 個上班族做超音波檢查發現，罹患脂肪肝的比例高達43%，其中男性上班族更高達49% (4)；另外，還有研究指出，台灣成人脂肪肝盛行率約三成，換句話說，大約每兩、三個成人當中就有一人得了脂肪肝，遠高於大家熟知的B型肝炎(20%)、C型肝炎(2～6%)，因此脂肪肝可說是台灣人最普遍的肝病(4)。脂肪肝形成的原因非常多，基本上是由於血中的遊離脂肪酸長時間維持在過高的狀態下，導致肝內脂肪酸大量堆積所導致，而遊離脂肪酸過高的原因有：脂肪組織或血漿中脂蛋白(lipoprotein) 與乳糜微粒(chylomicrons) 等脂肪過度水解；氧化減少，造成肝臟堆積；或是粒線體的合成作用增加等；亦可能是肝內脂肪酸轉化成三酸甘油酯後，因為脂蛋白(apoprotein)的缺乏，無法形成極低密度脂蛋白(VLDL)，因而使三酸甘油酯滯留在肝細胞內所造成，根據這樣的理論，可知長期攝取高脂飲食、過度饑餓、糖尿病控制不良、或血脂肪過高等情況，均容易導致脂肪肝之生成。另外，酒精會抑制脂肪酸氧化，因而導致脂肪肝甚至會演變成

肝炎、肝硬化和肝癌。

荷葉 (*Nelumbo nucifera* leaf)

蓮，別名為荷。多年生水生草本。根莖肥厚橫走，外皮黃白色，節部縊縮，節上生鱗片葉及鬚根。葉伸出水面，圓盾形，直徑 25～90 公分，全緣稍呈波狀，上面暗綠色，光滑具白粉，下面淡綠色，葉柄粗大，著生於葉背中央，圓柱形，中空，高達 1～2 尺，有刺毛。

荷葉始載於《本草綱目》，列於果部菰類蓮藕項下；嫩者稱荷錢，貼水者名藕荷，出水者是芰荷。《神農本草經》將蓮藕列為上品，謂其根為藕，其實為蓮，其莖葉為荷，皆指荷葉而言。荷葉為常用中藥。屬睡蓮科植物蓮（*Nelumbo nucifera Gaertn.*--睡蓮科 *Nymphaeaceae*）的葉。

1. 背景介紹：

植物蓮學名 *Nelumbo nucifera Gaertnero*。英名 East lndian Lotus，俗稱 Lotus，中文亦稱「荷」、「蓮」，是宿根性多年生水生植物。蓮在印度、中國及日本菲律賓等國皆有產，但主產地在印度，近百年內才由日本傳入臺灣，並開始大量種植，主要分佈在白河鎮及嘉義、台南市郊一帶，蓮的經濟作物以生產蓮子、蓮藕及藕粉等加工品為主(5)。

目前在台灣所種植的蓮，可分為四種：

(I) 大憨蓮：又稱大賀蓮，相傳源自於日本大賀一郎博士，在地下泥

碳層中，發現的千年古代蓮子，花色桃紅，形狀大且高出於荷葉，蓮蓬大，蓮子多，是為橢圓型的蓮子。目前是國內種植面積最廣，其蓮子與蓮藕都可採收，也最受到人喜歡欣賞及攝影。

(II) 見蓮：據傳是從福建傳來，花瓣較圓色粉紅，蓮子短橢圓形（圓粒），蓮蓬似漏斗型。花枝大多在葉下，花期長達三個月以上，蓮子產量高且清甜可口。葉背有許多點狀棗紅色素，有時在蓮蓬外側亦會出現棗紅斑紋。

(III) 石蓮：台灣最早的品系，花色因為雜交的結果，有粉紅、紅、白等顏色。石蓮主要用來採收蓮藕製藕粉，花可製成蓮花茶。石蓮的花得數量較少。種植面積最少的品種，但卻是屬於名貴的中藥材。

(IV) 菜蓮：菜蓮的葉形最大，蓮藕也特別粗狀，花色白數量少，蓮子也很少，主要以採藕為主，無法用來製作藕粉，主要供做菜用，故稱「菜蓮」。一般菜市場常見的蓮藕便是由菜蓮採收的。

蓮用途多在庭園造景欣賞及供人食用，故為著名食用、藥用兼觀賞植物，經濟價值極高。主要構造包括有：蓮花、蓮蓬、蓮鬚（雄蕊）、蓮子、蓮梗、蓮葉（荷葉）、蓮藕地下莖、蓮藕節等等。蓮花即為蓮之開花部分，於花中央者蓮蓬則為蓮蓬，嵌在蓮蓬中的種子即蓮子，葉片部分則稱為荷葉，根莖肥厚即為藕，蓮藕節則是位在蓮蓬之間的結節。

地下莖（蓮藕）與種子（蓮子）是我們常用的食品，葉片則常作為包裹的材料和中藥材入藥。荷葉為夏、秋二季採收，曬至七八成乾時，除去葉柄，折成半圓形或摺扇形，乾燥。 荷葉為蓮之葉片部分，形狀大多呈橢圓形，為常用中藥。

接著以荷葉為主之研究詳加介紹。

2. 化學成分

目前知道荷葉含多種生物鹼：如荷葉鹼（nuciferine）、N-去甲荷葉鹼（N-nornuciferine）、*o*-去甲荷葉鹼（*o*-nornuciferine）、牛心果鹼（anonaine）、繞袂鹼（roemerine）、亞美帕鹼（armepavine）、N-甲基衡州烏藥鹼（N-methylcoclaurine）、原荷葉鹼（pronuciferine）、鵝掌楸鹼（liriodenine）及去氧繞袂鹼（dehydroroemerine）(6)等等。荷葉也另含抗氧化物質類黃酮：荷葉苷（nelumboside）(7)、Oligomeric Procyanidins 及其槲皮素、異槲皮甙(8, 9)，以及維生素 C、酒石酸、枸櫞酸、蘋果酸、草酸、琥珀酸、葡萄糖酸、鞣質。另外，還含抗有絲分裂作用的鹼性成分(10)。

3. 生理活性

荷葉其味苦澀，性平微溫，入心、肝、脾三經，且具清解暑熱、散瘀止血之功效，主治暑溼泄瀉、水氣浮腫眩暈。本草綱目中記載：荷葉服之，令人瘦劣，單服可以消陽水浮腫之氣；本草再新稱荷葉：

清涼解暑、止渴生津、止瀉痢、去火熱。目前中醫則用於解「清暑利濕、升發清陽」之用。而荷葉自古代唐楊貴妃飲用荷葉茶以減輕體重即著名，近代臨床實驗亦多著重於荷葉對肥胖症(11)及高血脂症的效果(12)。但近五年來，對荷葉方面研究最多的中國大陸學者則多將研究方向逐漸轉移至抗氧化領域。荷葉的生理功效如下：

(a) 降血脂

複方荷葉沖劑能降低高脂血症之兔子的血清膽固醇及三酸甘油酯，對動物組織中脂質沉澱和粥狀動脈硬化，具抑制作用(13, 14)。以 95%乙醇、80℃、1.5 小時萃取之萃取物，證實對高脂血症的小鼠具良好之降血脂作用，可降低其血清中膽固醇(12)。荷葉複方飲可改善高血脂症大鼠的血液黏稠程度（全血比黏度），且明顯降低 TC、TG、LDL-C、和 AI 值，減緩體重增長及抑制脂肪肝的發生(15)。荷葉水煎劑能使高脂血症大鼠的 TC 下降 25.6~39.3%，TG 下降 18.9%~39.2%，同時也降低全血比黏度，進而改善血液黏稠狀況(16)。80℃浸泡 30 分鐘荷葉複方保健茶包袋能明顯降低 SD 大鼠血中 TG 及 TC(17)。

(b)抗氧化

以 90℃、10 倍於荷葉原料體積的水萃取 20 分鐘，所得之水萃物可有效清除超氧陰離子自由基及 Fenton 反應下產生的 OH・，且清除其氧自由基的能力隨著萃取物濃度上升而上升。而以 0.1% 提取

液飼餵果蠅可延長其壽命 17% 以上(14)。荷葉具有非常優良的抗氧化劑之潛力，在較低濃度和不需要特別精製的情況下即可顯示出非常強的抗氧化能力(18)。以 80℃、30 倍於荷葉原料體積的水萃取 1.5 小時所得之水萃取物對超氧陰離子自由基及 OH・有很強的清除效果，而且對超氧陰離子的清除能力比較強(19)。以荷葉單方水萃物餵食高脂模式的倉鼠，可使倉鼠肝中過氧化物質明顯降低(20)。荷葉萃取物除具良好清除自由基能力外，並可抑制人體離體 LDL 的氧化(21)。

荷葉在研究中較具代表性及說服力的功效為抗氧化與降血脂兩大方面，根據前人對荷葉中的有效成分之分析，大多認為荷葉中的類黃酮（flavonoids）及生物鹼（alkaloids）(19, 22, 23) 是其主要有效成分，最近我們的研究也顯示荷葉萃取物具有抑制血脂肪、血管病變及排除脂肪肝之作用(24-26)。

研究目的

隨著時代的進步，普遍飲食的精緻化，肥胖成為開發國家中最常見的營養過剩之病徵，也相對地提高其他疾病的發生，諸如：糖尿病、高血壓、高脂症、心血管疾病及癌症等。我們已經證實荷葉水萃物可誘導平滑肌細胞走向細胞凋亡，也證實荷葉萃取物的確促使增生的平滑肌細胞走向細胞凋亡的路徑，另外，亦發現荷葉萃取物有抑制平滑肌細胞遷移的能力，我們也進一步證實荷葉萃取物可抑制餵食高脂肪食物誘導兔子之三酸甘油脂、膽固醇，並抑制動脈粥狀硬化，如此的結果顯示荷葉可成為抑制心血管疾病的保健食品。本研究致力於開發荷葉萃取物，探討降血脂，抑制血管病變，降低肝臟脂肪，及不易形成體內脂肪之目的並與廠商合作開發為上述功能之健康食品，並推廣農產品之利用，以增進農產經濟。

材料與方法

高膽固醇飲食誘導倉鼠形成脂肪肝之模式

動物模式以 Syrain 雄性倉鼠為實驗動物，購自國家研究院實驗動物中心，小鼠購入時約為六週齡，體重約為 90 克左右，飼養於中山醫學大學動物中心，生活週期維持 12 小時光照、12 小時黑暗，光照時間為早上 6 時至下午 6 時，室溫維持 22 ± 2℃。進入實驗前充分供應飼料及飲水。待倉鼠適應環境後，開始進入本試驗。隨機將動物分成四組，控制組(normal control)、誘導組(induced control)、試驗組 I (NLE 1%)與試驗組 II (NLE 2%)，以每組 10 隻為一組的方式飼養。分組如下：

Group A : 控制組(normal control)，Purina Lab Diet 5001

Group B : 誘導組(induced control)，89% Purina LabDiet 5001 + 10% coconut oil + 0.2% cholesterol

Group C : 試驗組 I (NLE 1%)，89% Purina LabDiet 5001+ 10% coconut oil + 0.2% cholesterol) + 1% NLE

Group D : 試驗組 II (NLE 2%)，89% Purina LabDiet 5001+ 10% coconut oil + 0.2% cholesterol + 2% NLE

正常飼料(Purina Chow)購自 Purina (St. Louis, USA)，型號為 5001，儲存於室溫下。誘導組餵食之飼料包含 10% coconut oil 與 0.2% cholesterol。飼料之給予，於每日下午五點至五點 30 分移除舊的飼料置入新飼料，並紀錄每日倉鼠之攝取情形，並將其飲用水補足。實驗期達 10 週，實驗期間每週紀錄體重之變化，待實驗期間結束，將倉鼠犧牲取其血液做血糖、血清生化，包含肝功能(AST、ALT)及腎功能(BUN、creaitinine)、血脂含量分析(包含 triglyceride、free fatty acid、total cholesterol、LDL-c、HDL-c)、血中酮體濃度及電解質平衡狀態

分析。

高膽固醇飲食誘導小鼠形成脂肪肝之模式

動物模式以 C57BL/6 雄性小黑鼠為實驗動物，購自國家研究院實驗動物中心，小鼠購入時約為六週齡，體重約為 20 克左右，飼養於中山醫學大學動物中心，生活週期維持 12 小時光照、12 小時黑暗，光照時間為早上 6 時至下午 6 時，室溫維持 22 ± 2℃。進入實驗前充分供應飼料及飲水。待小鼠適應環境後，開始進入本試驗。隨機將動物分成四組，控制組(normal control)、誘導組(induced control)、試驗組 I (NLE 0.5%)與試驗組 II (NLE 1.5%)，以每組 10 隻為一組的方式飼養。分組如下：

Group A : 控制組(normal control)，Purina Lab Diet 5001

Group B : 誘導組(induced control)，89% Purina LabDiet 5001 + 20% lard oil + 0.5% cholesterol

Group C : 試驗組 I (NLE 0.5%)，89% Purina LabDiet 5001+ 20% lard oil + 0.5% cholesterol) + 0.5% NLE

Group D : 試驗組 II (NLE 1.5%)，89% Purina LabDiet 5001+ 20% lard oil + 0.5% cholesterol + 1.5% NLE

正常飼料(Purina Chow)購自 Purina (St. Louis, USA)，型號為 5001，儲存於室溫下。誘導組餵食之飼料包含 20% lard oil 與 0.5% cholesterol。飼料之給予，於每日下午五點至五點 30 分移除舊的飼料置入新飼料，並紀錄每日小鼠之攝取情形，並將其飲用水補足。實驗期達 6 週，實驗期間每週紀錄體重之變化，待實驗期間結束，將小鼠犧牲取其血液做血糖、血清生化，包含肝功能(AST、ALT)及腎功能(BUN、creaitinine)、血脂含量分析(包含 triglyceride、free fatty acid、total cholesterol、LDL-c、HDL-c)、血中酮體濃度及電解質平衡狀態分析。

肝臟重量變化之測定

待實驗結束後，將實驗動物犧牲，取出體內之肝臟組織，並秤重紀錄之。

肝臟中脂質含量變化

待實驗期間結束後，將實驗動物犧牲並摘取其 0.5g 之肝臟組織，再以 0.5 ml 之 hexane : isopropanol (3:2, v/v) 萃取肝臟所含之脂質，將脂質萃取物移至玻璃離心管中自然風乾，再以 200 μl 的 isopropanol 回溶，即可得肝臟內脂質萃取液，再利用市售之酵素測定法試劑，測定肝臟內脂質含量之變化 (包含 triglyceride, total cholesterol)。

統計分析

試驗過程每組皆三重複以上，採用 Student's t-test 統計分析，凡 $p<0.05$ 以下時表示為有意義的差異。

結果與討論

1. 體重之變化

由 Table. 1 可以得知，在高熱量的飼料(HFD) 餵食倉鼠的模式下，誘導組倉鼠的體重有明顯地上升，而隨著餵食的週數增加，體重上升的變化也更加地顯著(達 37%)；相對的在餵食荷葉萃取物的組別，無論是 NLE 1% 或是 NLE 2% 皆可以看到體重增加的趨勢，有因為 NLE 的餵食而受到抑制。相似的結果也可以從不同的實驗動物(C57BL/6 mice model) 下觀察得到，在 HFD 餵食下，誘導組的體重有快速地上升，在第 6 週時增加到 21%；而在餵食荷葉萃取物的組別中，NLE 0.5%與 1.5% 可以有效地抑制體重增加(Tab. 2)。由上述的結果顯示，荷葉萃取物能夠有效地減緩體重的上升。

2. 攝食量的改變

在倉鼠的模式下，可以觀察到各組之間的攝食量變化並沒有統計學上的差異(Fig. 1)；然而在 C57BL/6 小鼠的模式中，雖然看到 HFD 誘導組的攝食量有上升，而餵食 NLE 的組別有下降的趨勢，但是這樣的結果仍然沒有統計學上的意義(Fig. 11)。

3. NLE 有效地降低血中脂肪的含量

倉鼠在經由 HFD 誘導 10 週後，其血中的脂肪(總膽固醇與三酸甘油酯)含量皆比顯著地高於正常對照組，其中總膽固醇含量甚至高

達正常對照組的三倍(Fig. 2)。但是在同時餵食 NLE 1% 或 NLE 2% 的組別中，其血中之總膽固醇與三酸甘油酯均低於誘導組，總膽固醇也僅有誘導組的一半，三酸甘油酯也低於誘導組，並與正常對照組相差不遠(Fig. 2)。相似的結果也可由 C57BL/6 小鼠的模式中得到驗證(Fig. 12)。值得一提的是，C57BL/6 小鼠的模式中所選用的荷葉萃取物的劑量低於倉鼠的試驗組，但也得到相似的結果，顯示荷葉萃取物確實具有降低血中脂肪(總膽固醇與三酸甘油酯)含量之能力。

4. NLE 有效地減緩血中脂蛋白的含量

接著我們觀察 NLE 對於 HFD 誘導的模式下，對於血中脂蛋白的影響。從結果得知，在 HFD 的誘導下，血中的低密度脂蛋白(LDL-c)的含量確實有增加，而 LDL-c/HDL-c 的比值也有上升的趨勢，顯示在 HFD 誘導下倉鼠血中的脂蛋白含量確實有比較高，但是在 NLE 餵食下，其血中的 LDL-c 卻有顯著地降低，但是 HDL-c 卻沒有明顯上升，意味著 NLE 是透過降低 LDL-c 來達到調節血中脂蛋白的含量變化(Fig. 3)。而在小鼠的模式中，小鼠在 HFD 的誘導下，LDL-c 與 LDL-c/HDL-c 的比值也有上升，而同時餵食 NLE 的試驗組也可觀察到這兩個數值的下降，但是卻沒有統計學上的意義，但是我們也可從結果中觀察到 NLE 餵食的小鼠中，其 HDL-c 有上升的趨勢，雖沒有統計學上的差異，但似乎說明 NLE 也可以透過 HDL-c 的增

加來改善血中脂蛋白的變化(Fig. 14)。另外，在小鼠的模式下也可以觀察到 NLE 能夠有效地降低血中游離脂肪酸的含量(Fig. 13)。

由上述所顯示的結果可以得知，無論是在倉鼠或小鼠的模式中，NLE 皆有效地降低血中的脂肪、脂蛋白或游離脂肪酸的含量，透過這樣的調節方式減緩體內的脂肪含量增加，進而達到減少體重的增加。

5. NLE 有效地減緩肝臟的脂肪堆積

上述的結果顯示，NLE 能夠降低血中的脂質含量上升，因此我們接著觀察 NLE 對於是否能夠影響調節脂質代謝的重要器官。首先我們觀察主要在代謝脂質的肝臟，萃取動物肝臟中的脂質做定量分析，觀察 NLE 對於肝臟中脂質含量的影響。由結果可以觀察到，在 HFD 的餵食下，誘導組的肝臟中脂質含量確實有明顯地上升，約為正常對照組的 3~4 倍，顯示高熱量的食物誘導下，確實會增加肝臟中的脂質堆積現象，而在 NLE 1% 或 NLE 2% 的同時餵食下，肝臟中的膽固醇或三酸甘油酯皆有下降的趨勢，且有隨著餵食 NLE 的劑量提升，而有所降低(Fig. 4)。相似的趨勢也出現在 C57BL/6 的小鼠模式中，較低劑量的 NLE 0.5% 即能夠有效的改善 HFD 所誘導的肝臟中膽固醇或三酸甘油酯的堆積(Fig. 15)。由小鼠的肝臟病理切片結果可以觀察到，在 HFD 誘導之下，肝臟細胞質中確實出現大量脂肪

油滴，甚至在肝臟中出現過量的脂肪堆積所造成的空泡現象，但是在同時餵食 NLE 0.5% 或 NLE 1.5% 的試驗組中可以看到，脂肪油滴或過量脂肪堆積所造成的空泡現象皆明顯地減少(Fig. 16)。

由上述的結果顯示，荷葉萃取物能夠減緩肝臟中脂質堆集的現象，意味著 NLE 具有改善脂肪肝行程的作用。

6. NLE 對於肝功能指標與腎功能指標的影響

肝臟細胞因為堆積過量的脂肪，進而影響正常的代謝作用，會導致肝臟功能受損或處於慢性發炎的狀態，造成肝功能指標蛋白會有上升的趨勢。因此我們緊接著觀察 NLE 對於肝功能指標的影響，結果發現，HFD 確實會造成肝臟中 AST 與 ALT 的增加，但是在飼料中同時加入 NLE 後，明顯地改善的 AST 與 ALT 的上昇 (Fig. 5)。同樣地，我們以 C57BL/6 的小鼠做實驗，也觀察到 NLE 具有降低肝功能指標蛋白 AST 與 ALT 的能力(Fig. 17)。顯示 NLE 具有保護肝臟功能之潛力。

同時我們觀察在 HFD 的誘導下會否造成腎功能之受損，結果顯示，不論是倉鼠模式(Fig. 6) 或是在 C57BL/6 的小鼠模式下(Fig. 18)，在本研究所採用的 HFD 模式，尚不至於造成腎臟的損傷，所以並不會影響血中腎功能指標的變化(皆無統計學上的差異)。

7. NLE 降低血中酮體的上升

當葡萄糖無法輸送到細胞時，脂肪會分解成葡萄糖及酮體，酮體濃度上升，酮體及葡萄糖會因滲透性利尿作用經腎臟排泄，水分由此大量流失而造成脫水，脫水又再讓血中葡萄糖濃度上升，脫水與血酮上升會使電解質不平衡，酮體累積過渡血液呈現酸性，代償未果則造成酸中毒。我們可以從結果得知，在 HFD 誘導下，血中的酮體有上升的現象，但是在同時餵食 NLE 1% 或 NLE 2%下，血中的酮體含量就有所下降，顯示 NLE 能夠降低血中酮體的增加(Fig. 7)。同樣的情形也出現在以 C57BL/6 小鼠作為模式的結果當中，在以 HFD 誘導下，會造成血中酮體的上升，而 NLE 0.5% 與 NLE 1.5% 皆能夠有效降低血中的酮體(Fig. 19)。而在高熱量的飲食下，除了會增加血中的脂肪、脂蛋白含量，進而造成代謝性的酮體增加外，也容易影響血中電解質的變化，所以我們接著觀察血中鈉與鉀的變化。由 Fig. 8 中得知，在本報告中所採用的 HFD 尚不至於造成血中的電解質有所改變，無論是鈉或鉀，而在 C57BL/6 的小鼠中也是同樣的情形，其變化皆無統計學上的意義(Fig. 20)。

8. 血醣之變化

在倉鼠的模式中，HFD 所誘導下，血糖並沒有太大的差異(Fig. 9)；但是在 C57BL/6 小鼠的模式中，即可發現 NLE 0.5% 與 NLE 1.5% 皆能夠降低血糖的含量，顯示 NLE 還是能夠透過調節血中脂

質的含量或肝臟中脂肪的堆積，進而影響血糖的變化(Fig. 21)。

9. NLE 減緩脂肪組織之堆積

由之前的結果顯示，NLE 能夠有效抑制血中脂質含量，降低血中脂蛋白變化，改善肝臟中脂質的堆積，所以我們接著觀察 NLE 對於實驗動物體內的脂肪組織的影響。由結果顯示，倉鼠在餵食 NLE 1% 或 NLE 2% 的情況下，皆能夠有效地降低 HFD 所誘導的脂肪組織增加(Fig. 10)；相似的作用在 C57BL/6 小鼠的模式也可觀察到，HFD 能夠顯著地增加小鼠體內的脂肪組織，而 NLE 0.5% 與 NLE 1.5% 皆有效地減緩小鼠體內的脂肪組織(Fig. 22)，總結上述的結果得知，荷葉萃取物具有改善體內脂肪堆積，不易形成體脂肪的潛力。

10. NLE 能夠減少脂解酶之活性與降低脂肪酸合成酶活性之作用

為了探究 NLE 是如何降低小鼠體內脂肪組織的作用，我們接著觀察在 NLE 餵食下，是否會影響脂解酵素(lipase) 的作用。結果發現，NLE 0.5% 與 NLE 1.5% 會降低 HFD 所誘導的 lipase 活性增加(Fig. 23)，同時我們發現，NLE 0.5% 與 NLE 1.5% 也能夠抑制脂肪酸合成酵素(fatty acid synthase) 的活性(Fig. 24)，因此我們可以猜測，荷葉萃取物是透過調節兩個主要脂肪合成的酵素活性作用，進一步去影響動物體內的脂肪堆積。

結論

隨著人口年齡的老化，平均壽命之延長，所遭遇到的疾病及健康問題也隨之增加，因此現代人不僅是要活得長，更要活得健康，有尊嚴，也相對顯示預防醫學的重要，飲食所造成的肥胖實乃代謝性相關疾病形成之主因。依目前健康食品之開發趨近成熟，而現今在市面上所流通之保健食品亦不計其數。最近衛生署也已針對"不易形成體脂肪"及"高脂糧誘導脂肪肝之護肝作用"公佈相關健康食品評估方法後，目前市場上僅有少數產品通過相關規範，並不足以滿足日趨增加的市場需求，荷葉自古以來均記載著對於『活血化淤』具有強大的功效，據研究指出荷葉含豐富抗氧物質，所以具代表性及說服力的功效為抗氧化與降血脂兩大方面。而荷葉本身目前用途不多，經濟效益不大，因此材料成本不大，又適合栽植，本研究證實荷葉萃取物可開發為多重功能之健康食品。

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實驗圖與表

Table 1. Relative body change of HFD treated hamsters.

Group	Week		
	2	6	10
Normal	19 ± 2.06%[#]	25 ± 1.74%	25 ± 1.98%
HFD	33 ± 6.13%	35 ± 6.78%	37 ± 6.59%
NLE- 1%	26 ± 0.68%[a]	34 ± 5.66%	34 ± 5.58%
NLE -2%	25 ± 9.56%[a]	34 ± 0.31%	33 ± 2.03 %
Silymarin	22 ± 8.08%[a]	36 ± 4.57%	31 ± 2.51%
Simvastatin	-6 ± 0.99%[b]	6 ± 4.71%[b]	11 ± 7.38%[b]

Normal, normal group; HFD, hamster fed HFD-induced group; NLE 1%, hamster fed high fat diet with 1% NLE group; NLE 2%, hamster fed high fat diet with 2% NLE group; Silymarin, hamster fed high fat diet with 100 mg/ml silymarin group; Simvastatin, hamster fed high fat diet with 1 mg/ml simvastatin group.

#, data = [(week X – week 0) / week 0] × 100 %

a, $P < 0.05$, with respect to high-fat diet-treated group

b, $P < 0.01$, with respect to high-fat diet-treated group

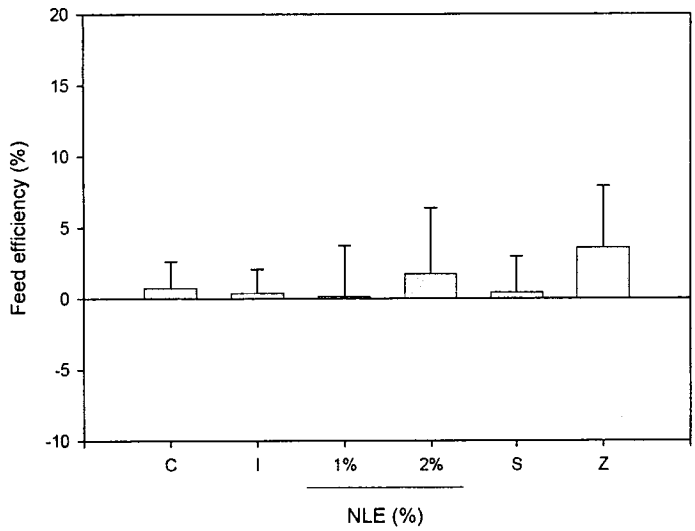


Figure 1. The feed efficiency of HFD fed hamster. Male Syrian (7 weeks old) hamsters were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of Syrian hamster was maintained on a high-fat diet (HFD) containing 10% coconut oil and 0.2% cholesterol for 10 weeks. C, normal group; I, hamster fed HFD-induced group; NLE 1%, hamster fed high fat diet with 1% NLE group; NLE 2%, hamster fed high fat diet with 2% NLE group; S, hamster fed high fat diet with 100 mg/ml silymarin group; Z, hamster fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

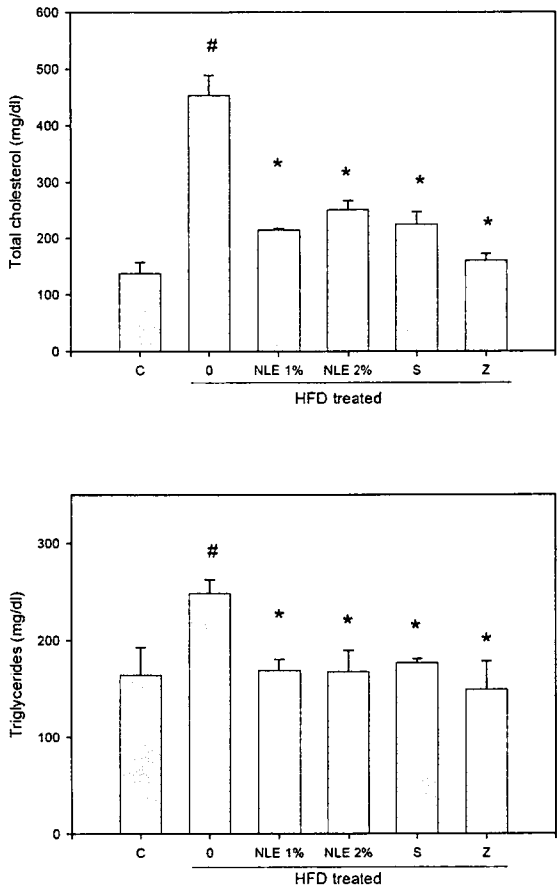


Figure 2. Total cholesterol and triglycerides content of HFD fed hamster. Male Syrian (7 weeks old) hamsters were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of Syrian hamster was maintained on a high-fat diet (HFD) containing 10% coconut oil and 0.2% cholesterol for 10 weeks. C, normal group; I, hamster fed HFD-induced group; NLE 1%, hamster fed high fat diet with 1% NLE group; NLE 2%, hamster fed high fat diet with 2% NLE group; S, hamster fed high fat diet with 100 mg/ml silymarin group; Z, hamster fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

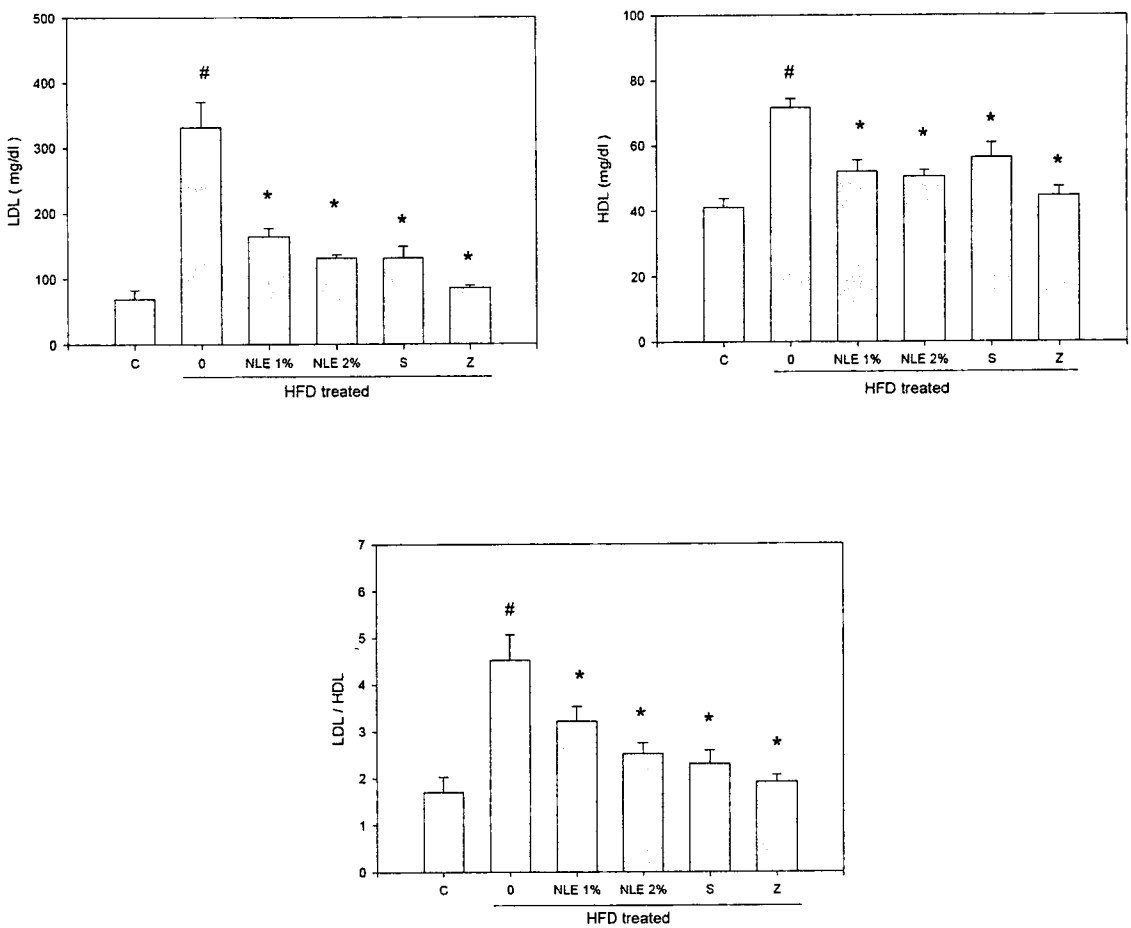


Figure 3. Total LDL-c and HDL-c content of HFD fed hamster. Male Syrian (7 weeks old) hamsters were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of Syrian hamster was maintained on a high-fat diet (HFD) containing 10% coconut oil and 0.2% cholesterol for 10 weeks. C, normal group; I, hamster fed HFD-induced group; NLE 1%, hamster fed high fat diet with 1% NLE group; NLE 2%, hamster fed high fat diet with 2% NLE group; S, hamster fed high fat diet with 100 mg/ml silymarin group; Z, hamster fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

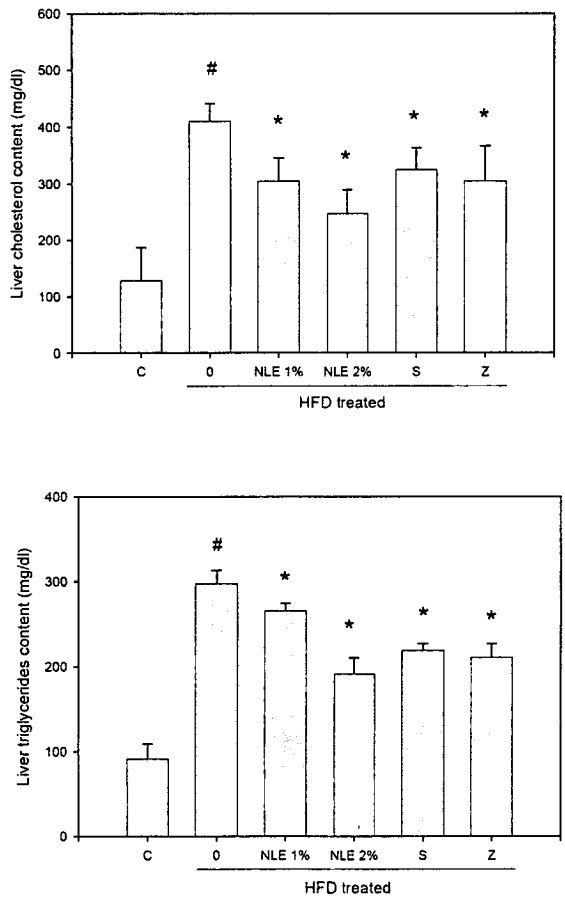


Figure 4. Total cholesterol and triglycerides content in liver of HFD fed hamster. Male Syrian (7 weeks old) hamsters were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of Syrian hamster was maintained on a high-fat diet (HFD) containing 10% coconut oil and 0.2% cholesterol for 10 weeks. C, normal group; I, hamster fed HFD-induced group; NLE 1%, hamster fed high fat diet with 1% NLE group; NLE 2%, hamster fed high fat diet with 2% NLE group; S, hamster fed high fat diet with 100 mg/ml silymarin group; Z, hamster fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

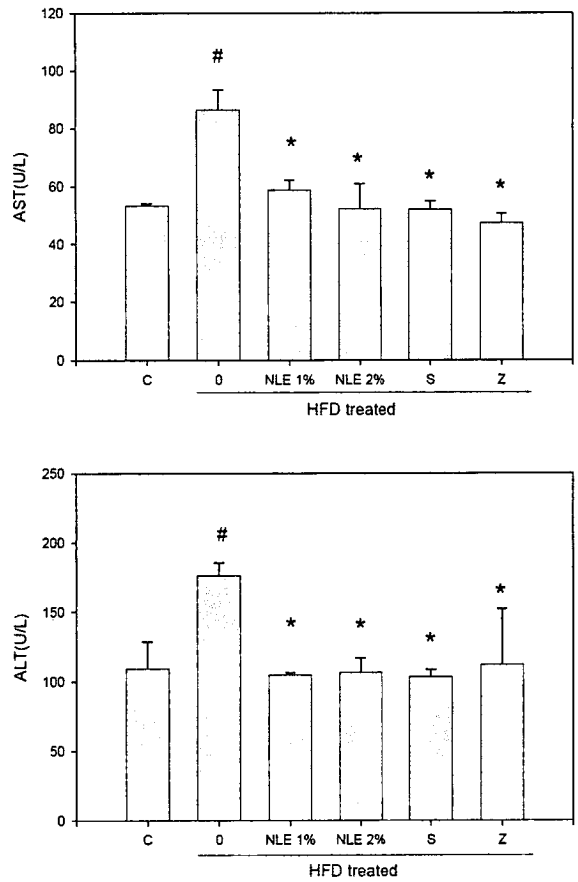


Figure 5. The AST and ALT activities of HFD fed hamster. Male Syrian (7 weeks old) hamsters were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of Syrian hamster was maintained on a high-fat diet (HFD) containing 10% coconut oil and 0.2% cholesterol for 10 weeks. C, normal group; I, hamster fed HFD-induced group; NLE 1%, hamster fed high fat diet with 1% NLE group; NLE 2%, hamster fed high fat diet with 2% NLE group; S, hamster fed high fat diet with 100 mg/ml silymarin group; Z, hamster fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

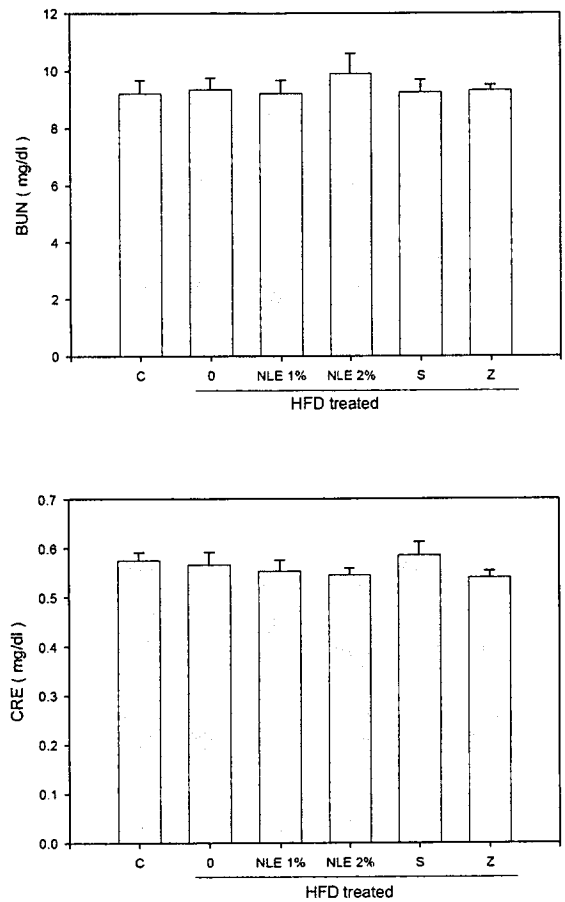


Figure 6. The BUN and CRE activities of HFD fed hamster. Male Syrian (7 weeks old) hamsters were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of Syrian hamster was maintained on a high-fat diet (HFD) containing 10% coconut oil and 0.2% cholesterol for 10 weeks. C, normal group; I, hamster fed HFD-induced group; NLE 1%, hamster fed high fat diet with 1% NLE group; NLE 2%, hamster fed high fat diet with 2% NLE group; S, hamster fed high fat diet with 100 mg/ml silymarin group; Z, hamster fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

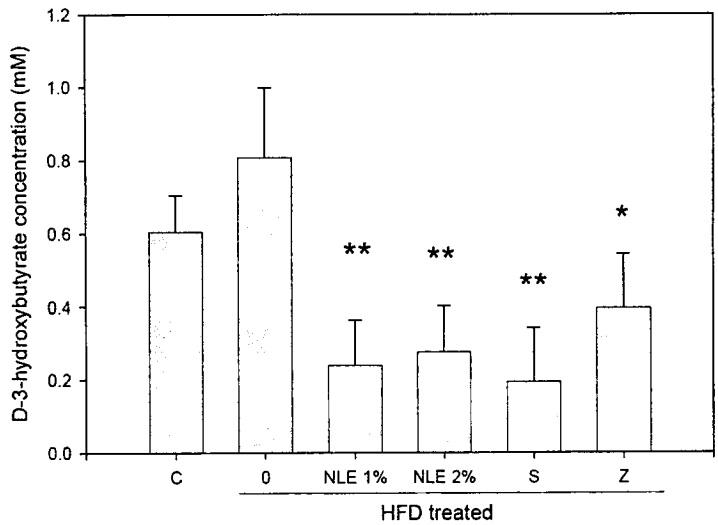


Figure 7. The keton body content of HFD fed hamster. Male Syrian (7 weeks old) hamsters were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of Syrian hamster was maintained on a high-fat diet (HFD) containing 10% coconut oil and 0.2% cholesterol for 10 weeks. C, normal group; I, hamster fed HFD-induced group; NLE 1%, hamster fed high fat diet with 1% NLE group; NLE 2%, hamster fed high fat diet with 2% NLE group; S, hamster fed high fat diet with 100 mg/ml silymarin group; Z, hamster fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

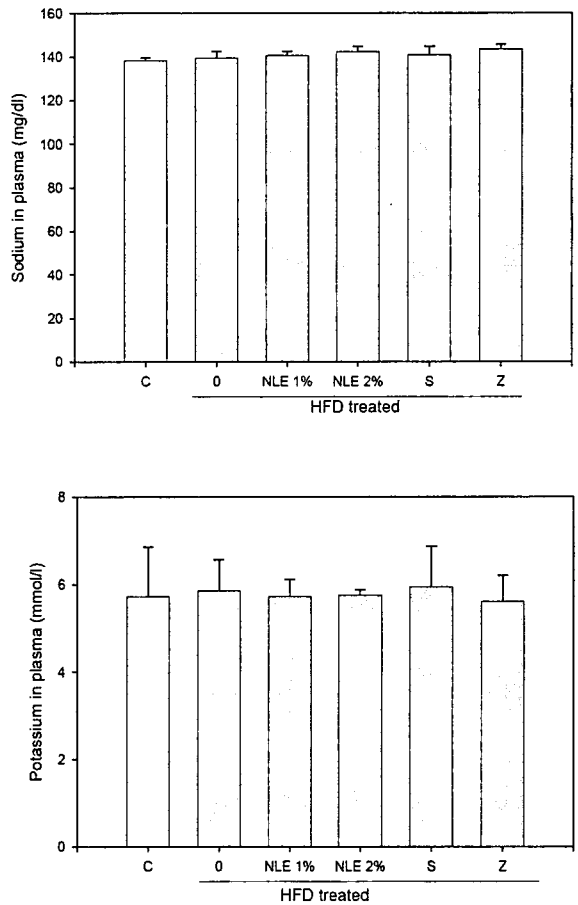


Figure 8. The sodium and potassium content of HFD fed hamster. Male Syrian (7 weeks old) hamsters were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of Syrian hamster was maintained on a high-fat diet (HFD) containing 10% coconut oil and 0.2% cholesterol for 10 weeks. C, normal group; I, hamster fed HFD-induced group; NLE 1%, hamster fed high fat diet with 1% NLE group; NLE 2%, hamster fed high fat diet with 2% NLE group; S, hamster fed high fat diet with 100 mg/ml silymarin group; Z, hamster fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

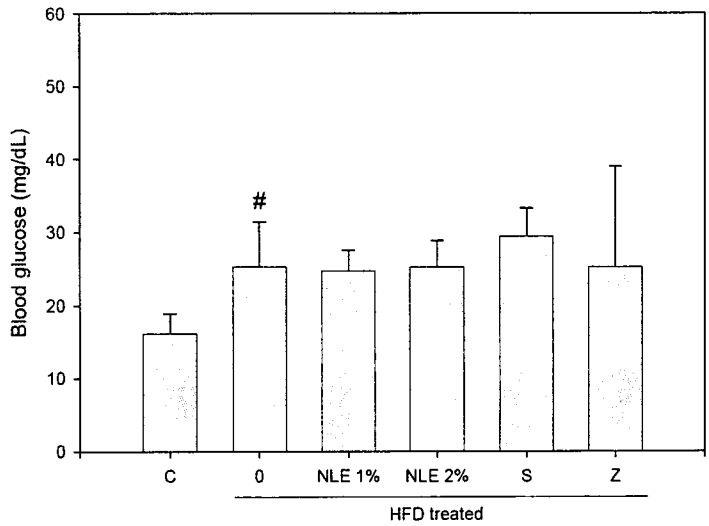
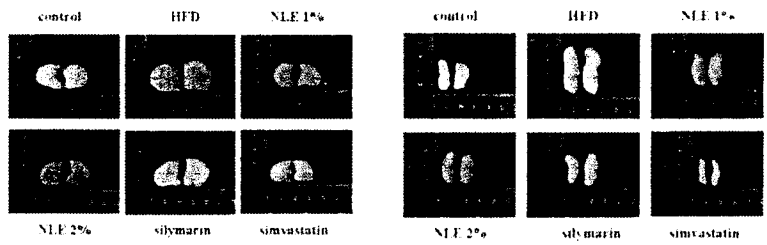


Figure 9. The blood glucose content of HFD fed hamster. Male Syrian (7 weeks old) hamsters were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of Syrian hamster was maintained on a high-fat diet (HFD) containing 10% coconut oil and 0.2% cholesterol for 10 weeks. C, normal group; I, hamster fed HFD-induced group; NLE 1%, hamster fed high fat diet with 1% NLE group; NLE 2%, hamster fed high fat diet with 2% NLE group; S, hamster fed high fat diet with 100 mg/ml silymarin group; Z, hamster fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.



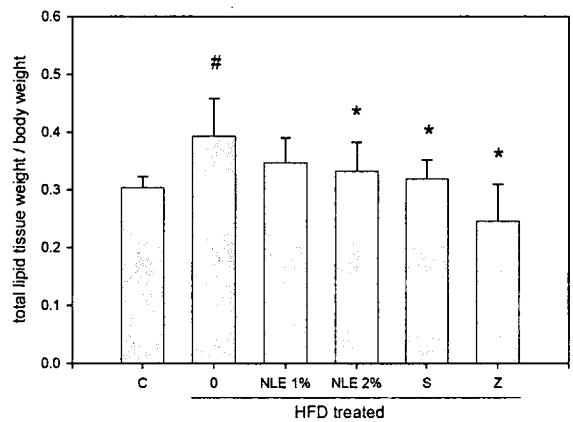


Figure 10. Total lipid tissue weight in HFD fed hamster. Male Syrian (7 weeks old) hamsters were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of Syrian hamster was maintained on a high-fat diet (HFD) containing 10% coconut oil and 0.2% cholesterol for 10 weeks. C, normal group; I, hamster fed HFD-induced group; NLE 1%, hamster fed high fat diet with 1% NLE group; NLE 2%, hamster fed high fat diet with 2% NLE group; S, hamster fed high fat diet with 100 mg/ml silymarin group; Z, hamster fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

Table 2. Relative body change of HFD treated mice.

	Control	HFD treated				
		HFD	NLE		Simvastatin	Silymarin
			0.5%	1.5%		
2 week	0.92 ± 0.41%[#]	1.18 ± 0.36%	1.93 ± 0.38%[b]	0.73 ± 2.38%	1.25 ± 1.96%	2.54 ± 1.58%
4 week	9.26 ± 1.13%	19.82 ± 1.45%	12.47 ± 2.43%	13.18 ± 2.70%[a]	15.55 ± 0.97%[a]	18.64 ± 1.71%[a]
6 week	12.39 ± 4.37%	21.00 ± 2.99%	14.14 ± 1.27%[a]	13.52 ± 2.43%[a]	17.56 ± 2.96%[a]	19.24 ± 1.80%[a]

Control, normal group; HFD, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; Silymarin, mice fed high fat diet with 100 mg/ml silymarin group; Simvastatin, mice fed high fat diet with 1 mg/ml simvastatin group.Data show values from male mice (n = 10) on the indicated treatments for 6 weeks as means ± SD.

#, data=[(week X – week 0) / week 0]×100 %

a, $P < 0.05$, with respect to high-fat diet-treated group

b, $P < 0.01$, with respect to high-fat diet-treated group

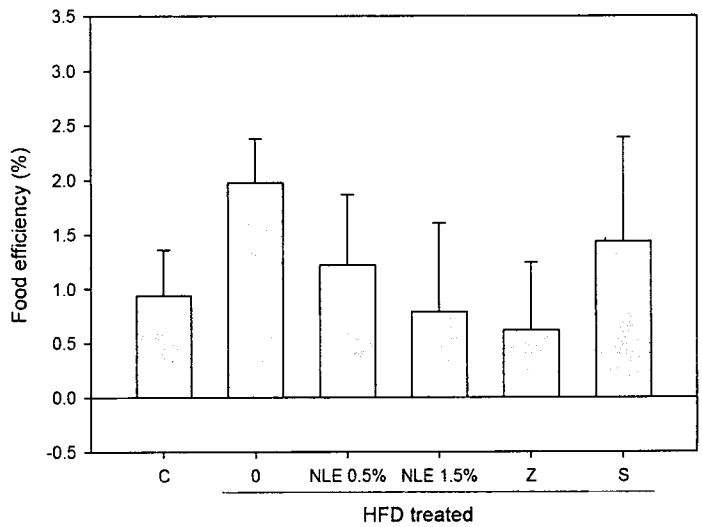


Figure 11. The feed efficiency of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

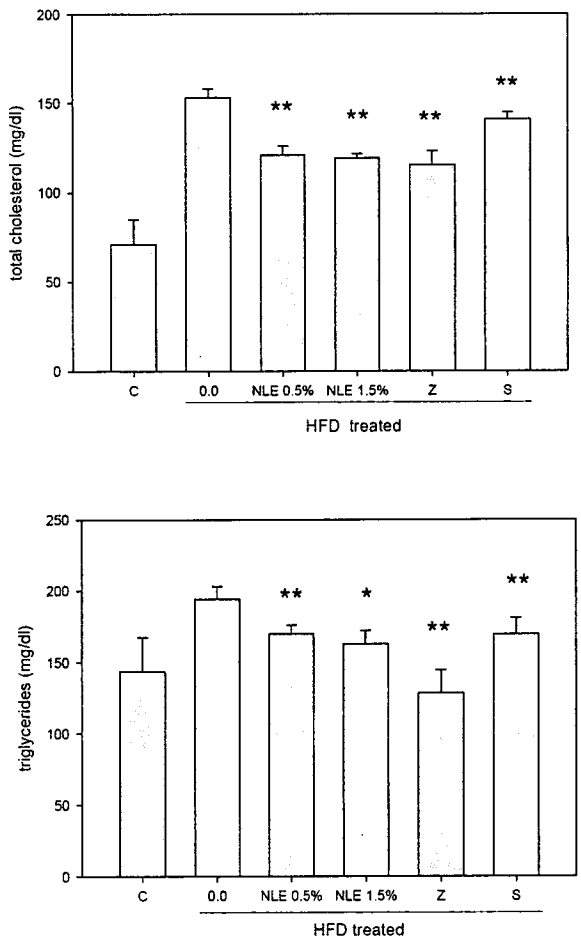


Figure 12. Total cholesterol and triglycerides content of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

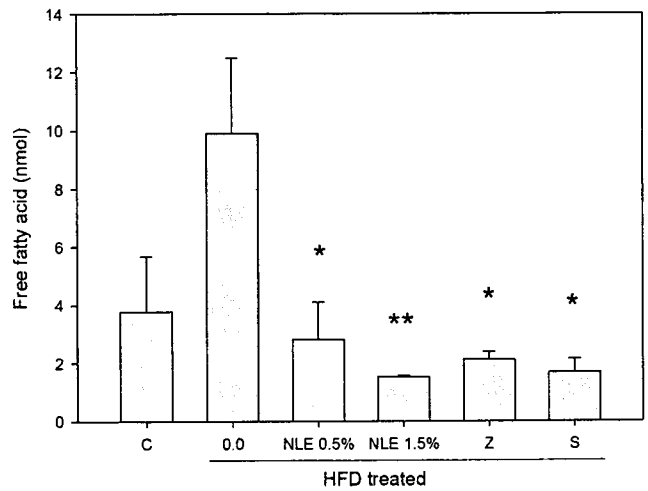


Figure 13. Free fatty acid content of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group

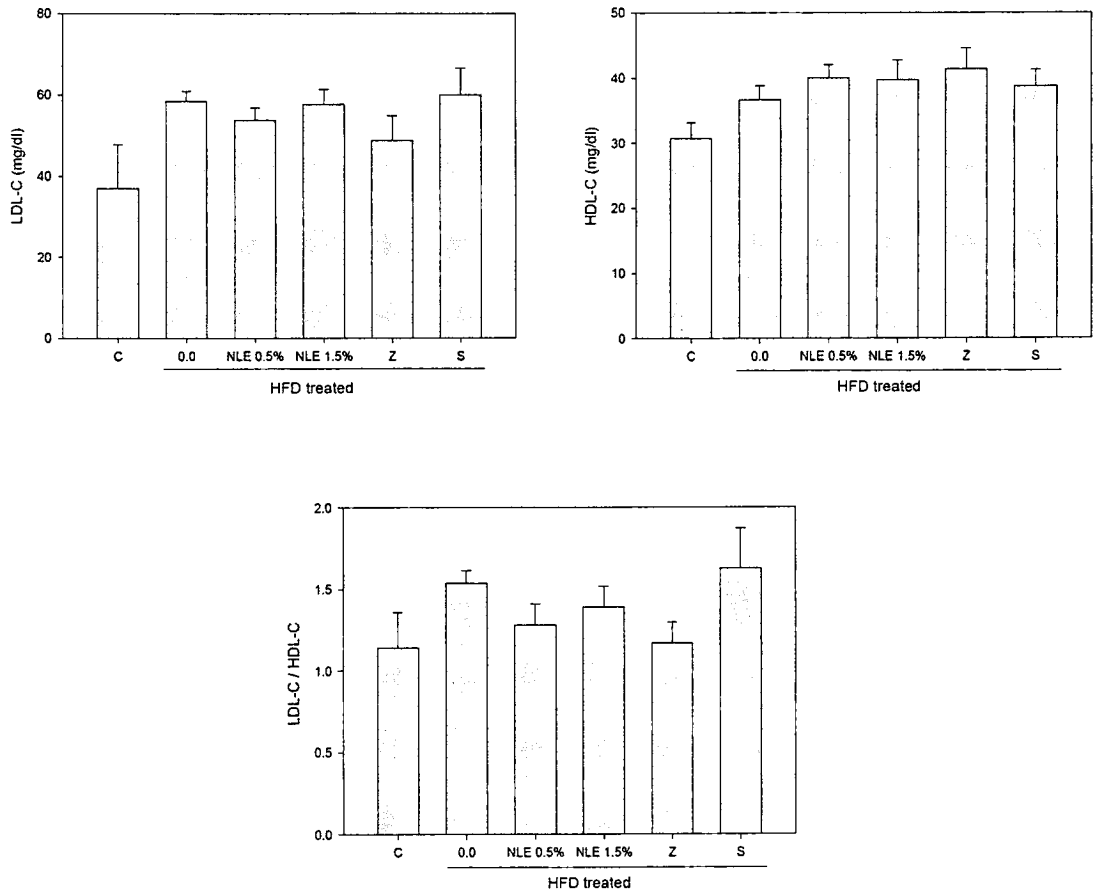


Figure 14. Total LDL-c and HDL-c content of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

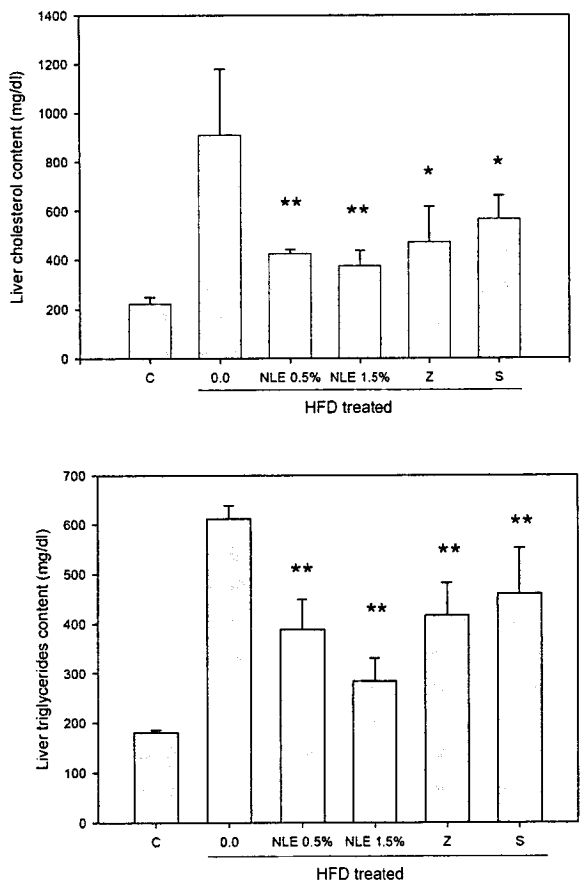


Figure 15. Total cholesterol and triglycerides content in liver of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

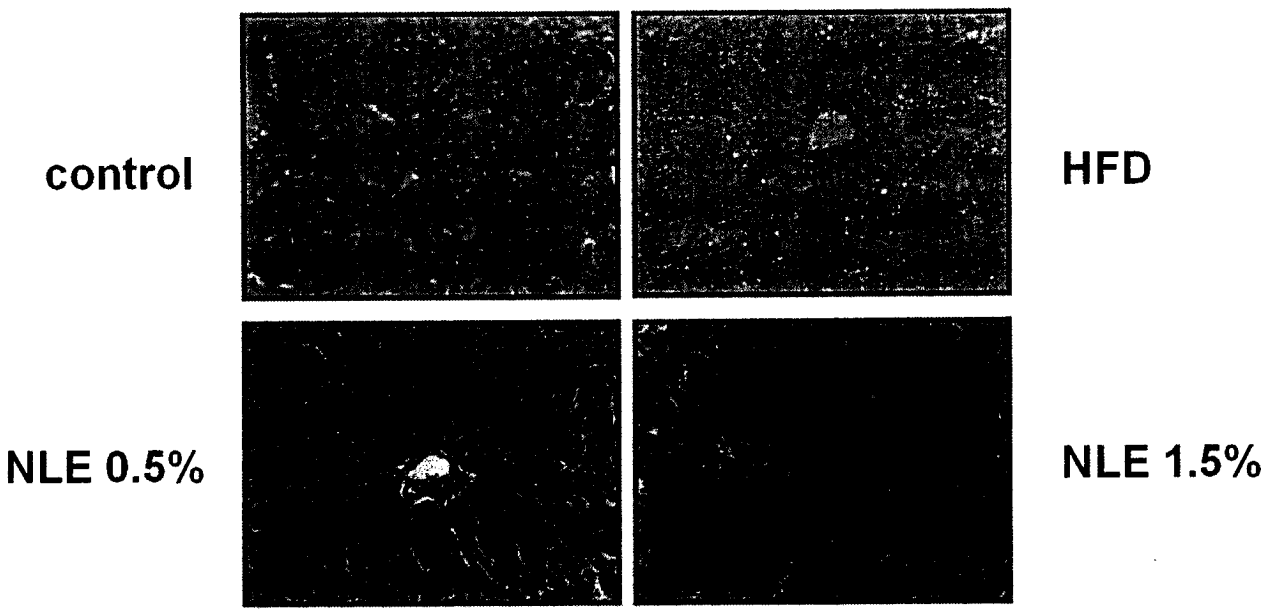


Figure 16. H&E staining of liver tissue in hamsters fed with control diet and HFD. Control, normal diet; HFD, HFD without NLE; 0.5%-NLE, HFD with 0.5 % NLE; 1.5%-NLE, HFD with 1.5% NLE. C57BL/6 mice in all groups were sacrificed after 6-week experiments. Liver tissues were obtained immediately after sacrifice and stained with H&E.

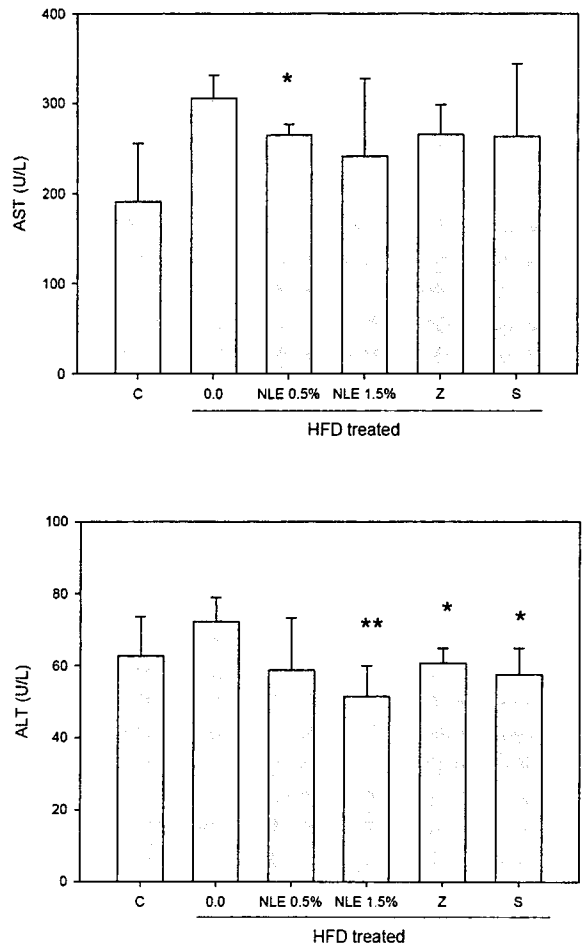


Figure 17. The AST and ALT activities of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

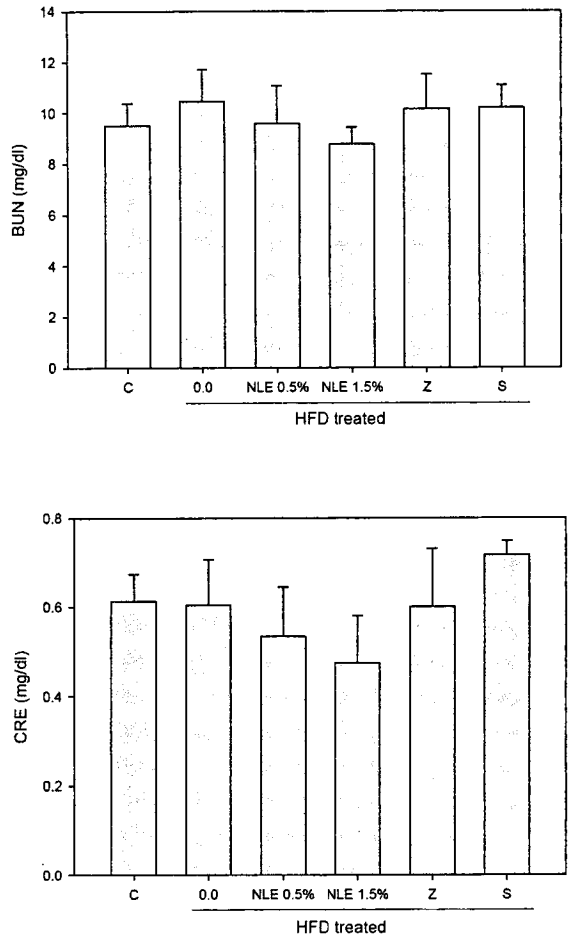


Figure 18. The BUN and CRE activities of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

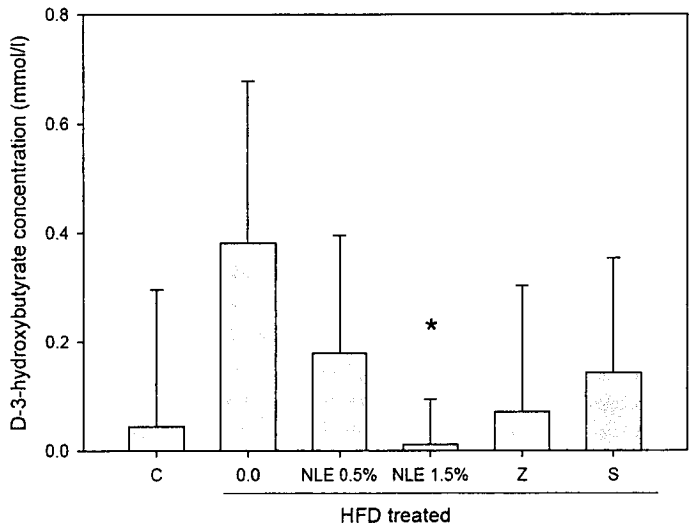
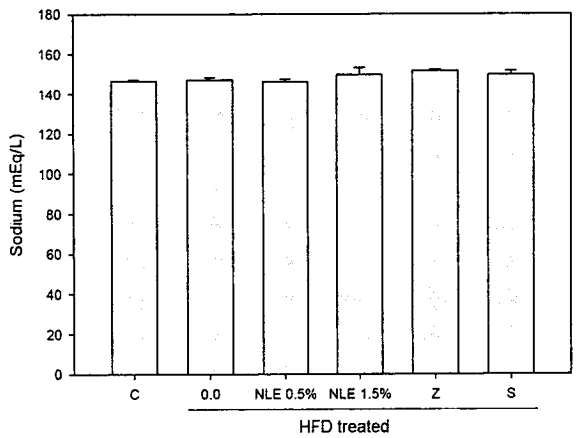


Figure 19. The keton body content of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.



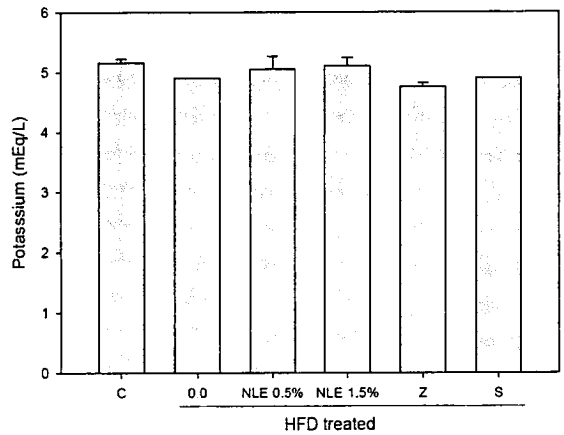


Figure 20. Total sodium and potassium content of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

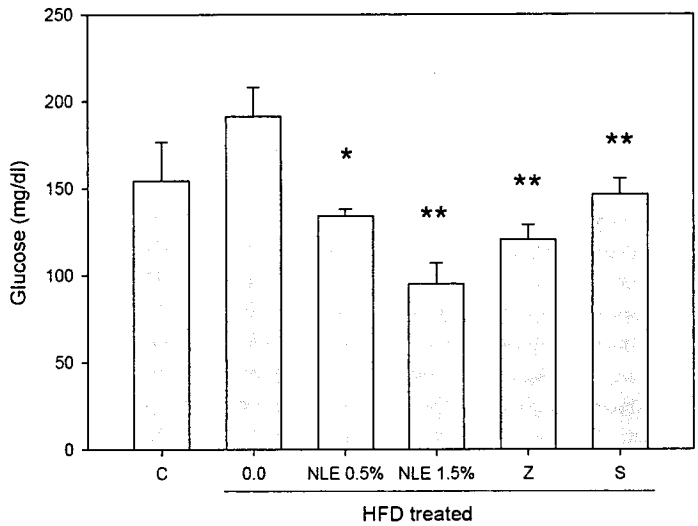


Figure 21. The blood glucose content of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

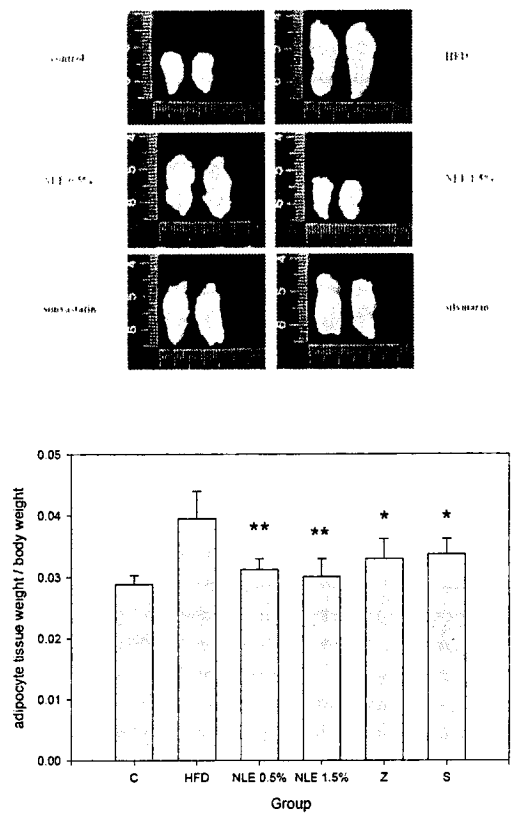


Figure 22. Total lipid tissue weight of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

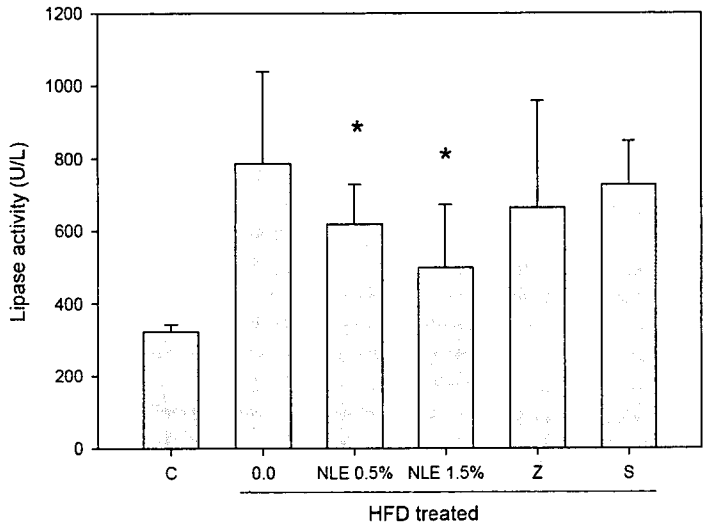


Figure 23. The lipase activity of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.

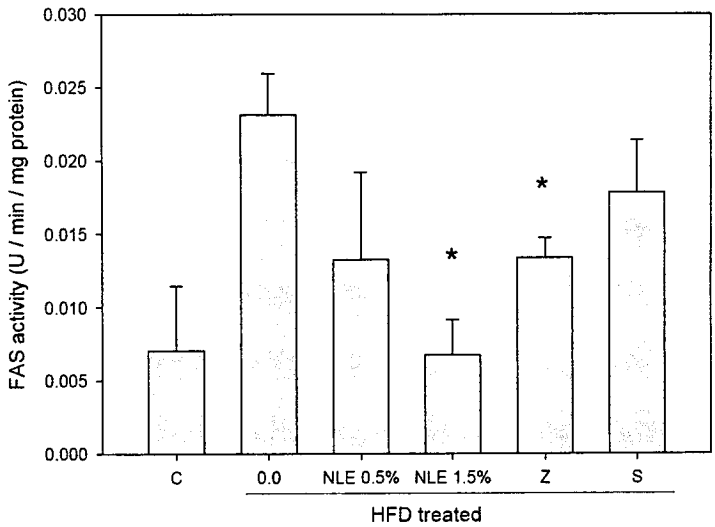


Figure 24. The fatty acid synthase activity of HFD fed C57BL/6 mice. Male C57BL/6 mice (5 weeks old) were individually housed and maintained at 25°C with a 12-h light/dark cycle. Induced group of mice was maintained on a high-fat diet (HFD) containing 20% coconut oil and 0.5% cholesterol for 6 weeks. C, normal group; 0, mice fed HFD-induced group; NLE 0.5%, mice fed high fat diet with 0.5% NLE group; NLE 1.5%, mice fed high fat diet with 1.5% NLE group; S, mice fed high fat diet with 100 mg/ml silymarin group; Z, mice fed high fat diet with 1 mg/ml simvastatin group. Data are shown as the means ± SD. *, P value < 0.05 was compared with induced group. #, P value < 0.05 was compared with normal group.