# Effects of High-Fat and High-Carbohydrate Diets on Lipid Metabolism in Rats: Postprint

**Authors:** Yang Ying, Wang Weiwei, Li Aike, Han Sihai, Liu Jianxue

**Date:** 2017-10-10T00:00:00+00:00

## Abstract

This study aimed to investigate the effects of high-fat and high-carbohydrate diets on lipid metabolism in rats at the same metabolizable energy level. Forty-eight 8-week-old male Sprague-Dawley (SD) rats were selected and randomly divided into 3 groups, with 8 replicates per group and 2 rats per replicate. The three groups were fed high-fat diet (HF group), high-carbohydrate diet (HC group), and control diet (CON group), respectively, for a 9-week experimental period. The results showed: 1) Compared with the CON group, the HF and HC groups showed no significant differences in initial body weight, final body weight, or daily weight gain ($P>0.05$), but exhibited extremely significant reductions in daily feed intake ($P<0.01$) and extremely significant increases in feed conversion efficiency ($P<0.01$). 2) There were no significant differences among groups in Lee' s index, kidney index, stomach index, spleen index, or liver index ($P>0.05$). 3) Compared with the CON and HF groups, serum triglyceride, total cholesterol, and high-density lipoprotein cholesterol levels in the HC group were significantly or extremely significantly increased ($P<0.05$ or $P<0.01$); compared with the HC and CON groups, serum glucose content in the HF group was extremely significantly increased ($P<0.01$), while serum urea nitrogen content was extremely significantly decreased ($P<0.01$). Compared with the CON group, hepatic triglyceride content in both HF and HC groups was extremely significantly increased ($P<0.01$), and hepatic total cholesterol content in the HF group was extremely significantly increased ($P<0.01$). 4) Compared with the CON group, hepatic phosphoenolpyruvate carboxykinase (PEPCK) mRNA expression levels in both HF and HC groups were extremely significantly increased ($P<0.01$); compared with the CON and HC groups, hepatic sterol regulatory element-binding protein 1 (SREBP1) mRNA expression levels in the HF group were extremely significantly increased ($P<0.01$). In conclusion, under the same metabolizable energy level, the HF and HC groups showed no significant increase in body weight. The HC group exhibited elevated blood lipids; the HF group showed increased serum glucose and hepatic total choles-

terol content, and decreased serum urea nitrogen content. Both HF and HC groups had increased hepatic triglyceride content and affected lipid metabolism through hepatic PEPCK and SREBP1 gene expression regulatory pathways.

## Full Text

# Effects of High-Fat Diet and High-Carbohydrate Diet on Lipid Metabolism in Rats

**YANG Ying[1],[2], WANG Weiwei[2], LI Aike[2], HAN Sihai[1], LIU Jianxue[1]***
[1]College of Food and Bioengineering, Henan University of Science and Technology, Luoyang 471023, China [2]Academy of State Administration of Grain, Beijing 100037, China

### Abstract

This study investigated the effects of high-fat and high-carbohydrate diets on lipid metabolism in rats under isoenergetic conditions based on metabolizable energy. Forty-eight 8-week-old male Sprague-Dawley rats were randomly divided into three groups (n=8 replicates per group, 2 rats per replicate) and fed either a high-fat diet (HF group), a high-carbohydrate diet (HC group), or a control diet (CON group) for 9 weeks. The results showed that: (1) Compared with the CON group, the HF and HC groups showed no significant differences in initial body weight, final body weight, or daily weight gain ($P>0.05$), but exhibited extremely significant reductions in daily feed intake ($P<0.01$) and extremely significant improvements in feed conversion efficiency ($P<0.01$). (2) No significant differences were observed among groups in Lee' s index, kidney index, stomach index, spleen index, or liver index ($P>0.05$). (3) Compared with the CON and HF groups, the HC group showed significant or extremely significant increases in serum triglycerides, total cholesterol, and high-density lipoprotein cholesterol ($P<0.05$ or $P<0.01$). Compared with the HC and CON groups, the HF group showed an extremely significant increase in serum glucose ($P<0.01$) and an extremely significant decrease in serum urea nitrogen ($P<0.01$). Compared with the CON group, the HF and HC groups showed extremely significant increases in hepatic triglyceride content ($P<0.01$), while the HF group also showed an extremely significant increase in hepatic total cholesterol content ($P<0.01$). (4) Compared with the CON group, the HF and HC groups showed extremely significant increases in hepatic phosphoenolpyruvate carboxykinase (PEPCK) mRNA expression ($P<0.01$). Compared with the CON and HC groups, the HF group showed an extremely significant increase in hepatic sterol regulatory element-binding protein 1 (SREBP1) mRNA expression ($P<0.01$). In conclusion, under isoenergetic conditions, the HF and HC groups showed no significant weight gain. The HC group exhibited elevated serum lipids, while the HF group showed increased serum glucose and hepatic total cholesterol but decreased serum urea nitrogen. Both HF and HC diets increased hepatic triglyceride content and affected lipid metabolism through

regulation of hepatic PEPCK and SREBP1 gene expression pathways.

**Keywords:** metabolizable energy; rats; fat; liver; SREBP1; PEPCK

## Introduction

Chronic consumption of high-fat and high-carbohydrate diets can induce obesity and lead to various complications in humans and animals, including cardiovascular disease, dyslipidemia, and metabolic syndrome. Maternal consumption of such diets also adversely affects offspring development. Previous studies have demonstrated that high-carbohydrate diets cause dyslipidemia and obesity in gerbils, while high-fat diets disrupt glucose and lipid metabolism in mice. Energy restriction has been shown to extend lifespan and control body weight. However, these studies were conducted under varying total energy levels. Since rats regulate food intake based on energy content, investigating the effects of dietary fat and carbohydrate under isoenergetic conditions is crucial. Most existing research has focused on total energy equivalence, but examining these effects under isoenergetic conditions based on metabolizable energy (the portion of dietary energy actually usable by animals) provides more scientific validity. Therefore, this study examined the effects of high-fat and high-carbohydrate diets on lipid metabolism in rats under isoenergetic conditions, while also measuring hepatic mRNA expression of SREBP1 and PEPCK to elucidate the underlying mechanisms. These findings will help clarify how excess dietary fat and carbohydrates affect metabolism at the physiological level and provide guidance for weight control strategies.

## Materials and Methods

### 1.1 Experimental Materials

**Reagents:** Hepatic triglyceride (TG) and total cholesterol (TC) assay kits were obtained from Nanjing Jiancheng Bioengineering Institute. RNA extraction and reverse transcription kits were purchased from Takara (Dalian, China). Real-time fluorescence quantitative PCR kits were provided by ABI.

**Instruments:** Synergy™ HT microplate reader (Biotek, USA), Centrifuge-5810R high-speed refrigerated centrifuge (Eppendorf, Germany), Roche biochemical analyzer (Roche, Switzerland), automatic oxygen bomb calorimeter (Parr-6300, USA), real-time fluorescence quantitative PCR instrument (ABI-7500, USA), and automatic gel imaging system (BIO-RAD, USA).

### 1.2 Experimental Design

Forty-eight 8-week-old specific-pathogen-free (SPF) male Sprague-Dawley rats weighing 319.69±2.73 g were purchased from Beijing Vital River Laboratory Animal Technology Co., Ltd. After a 7-day acclimation period, rats were randomly

divided into three groups (n=8 replicates per group, 2 rats per replicate) and fed either a high-fat diet (HF group), high-carbohydrate diet (HC group), or control diet (CON group). Diets were manufactured by Nantong Trophic Animal Feed High-Tech Co., Ltd., with vitamin and mineral premixes formulated according to AIN-93G standards. Diet composition and nutrient levels are presented in .

### 1.3 Animal Management

Rats were housed in an SPF animal facility (Academy of State Administration of Grain, Beijing) using individual ventilated cages (IVC) under controlled conditions: temperature 22±2°C, relative humidity 50%, and 12-hour light-dark cycle. A metabolic trial was conducted to determine digestible and metabolizable energy. Based on these measurements, pair-feeding was implemented using the HF group intake as baseline (feed intake × apparent metabolizable energy/body weight · ) to ensure isoenergetic intake across groups. The experimental period lasted 9 weeks.

### 1.4 Sample Collection and Analysis

**1.4.1 Serum and Tissue Sample Collection** Body weight and feed intake were recorded weekly. At the end of the experiment, rats were fasted for 12 hours, weighed, and euthanized by CO asphyxiation for cardiac blood collection. Blood was allowed to clot at room temperature for 4 hours, then serum was separated by centrifugation at 3,000 rpm for 10 minutes at 4°C and stored at -20°C until analysis. Body length (nose-to-anus) was measured, and kidneys, stomach, spleen, liver, and abdominal fat were dissected. Organs were rinsed with 0.90% saline, blotted dry, weighed, and organ indices calculated. Samples were snap-frozen in liquid nitrogen and stored at -80°C.

**1.4.2 Determination of Lee' s Index and Organ Indices** Lee' s index was calculated as: [body weight (g) × $10^3$ / body length (cm)]$^{1}/^{3}$. Organ indices were calculated as: (organ weight / body weight) × 100 for kidney, stomach, spleen, liver, and abdominal fat.

**1.4.3 Energy and Nutrient Analysis** The metabolic trial utilized 8-week-old SPF SD rats divided into three groups (n=8 replicates per group, 1 rat per replicate) fed the experimental diets for 7 days (3-day adaptation, 4-day collection). Feces and urine were collected twice daily at 08:00 and 20:00. Feces were sprayed with 0.5 mol/L sulfuric acid to prevent nitrogen volatilization, dried at 65°C for 48 hours, ground, and stored at -20°C. Urine was acidified with 2 mL of 0.1 mol/L HCl and stored at 4°C. Metabolizable energy was calculated as: ME = GE intake - energy in urine - energy in feces. Gross energy in feed, urine, and feces was determined using an oxygen bomb calorimeter. Nutrient composition was analyzed according to Chinese national standards: crude fiber (GB/T 6433–2006), crude ash (GB/T 6438–1992), crude protein (GB/T 6432 –1994), crude fat (GB/T 10359–2008), and moisture (GB/T 6435–2006).

**1.4.4 Serum Lipid Metabolism Indices** Serum TG, TC, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), glucose (GLU), and urea nitrogen (UN) were measured using an automatic biochemical analyzer.

**1.4.5 Hepatic TG and TC Analysis** Hepatic TG and TC contents were determined using commercial kits according to the manufacturer' s instructions, with absorbance measured by microplate reader after homogenization and centrifugation.

**1.4.6 Hepatic mRNA Expression of Lipid Metabolism-Related Factors**
**Total RNA Extraction:** Liver total RNA was extracted using Takara' s RNA extraction kit. RNA concentration was determined using a nucleic acid analyzer (Eppendorf, Germany), and integrity was verified by 1% gel electrophoresis. Samples with A /A ratios of 1.8–2.0 were stored at -80°C.

**Reverse Transcription:** Reactions were performed using Takara' s kit: 5× PrimeScript RT Master Mix (4 L), total RNA (1,000 ng), and RNase-free water to 20 L. Conditions: 15 minutes at 37°C, 5 seconds at 85°C. cDNA was stored at -20°C.

**Real-Time Quantitative PCR:** Primers for PEPCK, SREBP1, and GAPDH were designed using Primer Premier 5.0 based on rat gene sequences from NCBI and synthesized by Sangon Biotech (Shanghai). Primer sequences were: PEPCK (forward: GTGATGACATTGCCTGGATG, reverse: TTAATGGCGTTCG-GATTTGT), SREBP1 (forward: GCACAGCAACCAGAAACTCA, reverse: TCATGCCCTCCATAGACACA), and GAPDH (forward: GGTTGTCTCCT-GCGACTTCA, reverse: TGGTCCAGGGTTTCTTACTCC). PCR conditions: initial denaturation at 95°C for 10 minutes, followed by 40 cycles of 95°C for 15 seconds and 60°C for 1 minute, with a final melting curve analysis. Reaction mixture (10 L) contained 1 L cDNA, 5 L MIX, 0.4 L each primer, and water. Relative expression was calculated using the 2^(-ΔΔCT) method with GAPDH as reference.

### 1.5 Statistical Analysis

Data are expressed as mean ± standard deviation. One-way ANOVA was performed using SAS 9.0 software. Differences were considered significant at $P<0.05$ and extremely significant at $P<0.01$.

## Results

### 2.1 Effects of High-Fat and High-Carbohydrate Diets on Body Weight, Feed Intake, and Feed Conversion Efficiency

All rats remained healthy throughout the 9-week experiment with no mortality. As shown in [Figure 1: see original paper], body weight increased gradually over

time with no significant differences among groups (P>0.05). During week 1, no significant differences in feed intake were observed. In week 2, the CON group showed significantly higher intake than the HF group (P<0.05) but not the HC group. From week 4 onward, the CON group exhibited extremely significantly higher intake than both HF and HC groups (P<0.01) [Figure 2: see original paper].

As presented in , no significant differences were found among groups in initial weight, final weight, or daily weight gain (P>0.05). However, daily feed intake in the CON group was extremely significantly higher than in HF and HC groups (P<0.01), while feed conversion efficiency was extremely significantly lower (P<0.01).

### 2.2 Effects of High-Fat and High-Carbohydrate Diets on Lee' s Index, Abdominal Fat Percentage, and Organ Indices

No significant differences were observed among groups in Lee' s index, kidney index, stomach index, spleen index, or liver index (P>0.05) . However, the HF group showed an extremely significant 42.64% increase in abdominal fat percentage compared with the CON group (P<0.01).

### 2.3 Effects of High-Fat and High-Carbohydrate Diets on Serum Biochemical Indices

The HC group exhibited extremely significant increases in serum TG and TC compared with both CON and HF groups (P<0.01), and a significant increase in HDL-C (P<0.05). No significant differences were found in LDL-C among groups (P>0.05). The HF group showed extremely significant increases in serum GLU and decreases in serum UN compared with both HC and CON groups (P<0.01) .

### 2.4 Effects of High-Fat and High-Carbohydrate Diets on Hepatic TG and TC Content

Both HF and HC groups showed extremely significant increases in hepatic TG content compared with the CON group (P<0.01). The HF group also exhibited extremely significant increases in hepatic TC content compared with both HC and CON groups (P<0.01) [Figure 3: see original paper] [Figure 4: see original paper].

### 2.5 Effects of High-Fat and High-Carbohydrate Diets on Hepatic PEPCK and SREBP1 mRNA Expression

Both HF and HC groups showed extremely significant increases in hepatic PEPCK mRNA expression compared with the CON group (P<0.01). The HF group exhibited extremely significant increases in hepatic SREBP1 mRNA expression compared with both CON and HC groups (P<0.01) [Figure 5: see

original paper] [Figure 6: see original paper].

## Discussion

This study employed pair-feeding based on measured metabolizable energy to ensure isoenergetic intake across groups, thereby investigating the effects of dietary composition independent of energy content. Calculated as feed intake × apparent metabolizable energy/body weight · , values of 4.86, 4.77, and 5.03 for HF, HC, and CON groups, respectively, confirmed successful isoenergetic feeding.

Under these conditions, the HF group showed a trend toward increased body weight without significant differences compared with HC or CON groups, while both HF and HC groups exhibited extremely significant reductions in feed intake. Previous research demonstrated that energy-restricted high-fat diets combined with exercise significantly reduced body weight, while ad libitum high-fat feeding caused weight gain. Our findings, in the absence of exercise but with energy restriction, suggest that limiting energy intake from high-fat and high-carbohydrate diets effectively controls body weight. However, energy restriction may increase body fat deposition, as evidenced by the 42.64% and 17.26% increases in abdominal fat percentage in HF and HC groups, respectively. Although liver index showed increasing trends in HF and HC groups, no significant differences were observed in organ indices, suggesting minimal impact on organ weights under isoenergetic conditions.

Obesity is closely associated with abnormal glucose and lipid metabolism, often resulting from excessive dietary fat and carbohydrate intake. The HC group showed significant elevations in serum TG, TC, and HDL-C (increases of 64.49%, 26.18%, and 14.78% vs. CON), indicating that high-carbohydrate diets elevate serum lipids even under energy restriction. The HF group exhibited hyperglycemia with a 59.28% increase in serum GLU and a 25.09% decrease in serum UN compared with CON, consistent with known effects of high-fat feeding.

The liver is a central site for lipid metabolism, and high-fat/high-carbohydrate diets typically increase hepatic lipid levels. Hepatic TG and TC contents increased by 52.94% and 35.29% in the HF group, and 83.92% and 25.76% in the HC group, respectively, demonstrating that both diets promote hepatic lipid accumulation despite energy restriction.

Lipid metabolism involves coordinated regulation by enzymes and transcription factors through multiple signaling pathways. Hepatic TG synthesis is closely linked to glucose metabolism, with glycerol derived from glycolytic intermediates and fatty acids synthesized from acetyl-CoA. PEPCK is a key regulator of gluconeogenesis and fatty acid metabolism, and increased expression may promote TG synthesis and fat accumulation. SREBP1 plays a critical role in regulating fatty acid synthesis and mediates hepatic lipogenesis through feedback mechanisms. High-fat and high-carbohydrate diets upregulate SREBP1 to stimulate hepatic fat synthesis. Our results show that under isoenergetic con-

ditions, both diets increased hepatic PEPCK mRNA expression by 160% (HF) and 77% (HC), and SREBP1 mRNA expression by 131% (HF) and 23% (HC) compared with CON. These findings align with previous research demonstrating diet-induced upregulation of these key metabolic regulators.

## Conclusion

1. Under isoenergetic conditions based on metabolizable energy, high-fat and high-carbohydrate diets did not significantly affect body weight in rats.
2. High-fat diets increased serum glucose levels, while high-carbohydrate diets elevated serum TG, TC, and HDL-C levels.
3. Both high-fat and high-carbohydrate diets upregulated hepatic SREBP1 and PEPCK expression, thereby increasing hepatic lipid accumulation.

## References

[1] LA FLEUR S E, LUIJENDIJK M C M, VAN DER ZWAAL E M, et al. The snacking rat as model of human obesity: effects of a free-choice high-fat high-sugar diet on meal patterns[J]. International Journal of Obesity, 2014, 38(5): 643–649.

[2] SONG X L, KESTIN M, SCHWARZ Y, et al. A low-fat high-carbohydrate diet reduces plasma total adiponectin concentrations compared to a moderate-fat diet with no impact on biomarkers of systemic inflammation in a randomized controlled feeding study[J]. European Journal of Nutrition, 2015, 55(1): 237–246.

[3] SCHAEFER E J, RD J A G M, DANSINGER M L. The effects of low-fat, high-carbohydrate diets on plasma lipoproteins, weight loss, and heart disease risk reduction[J]. Current Atherosclerosis Reports, 2005, 7(6): 421–427.

[4] POUDYAL H, KUMAR S A, IYER A, et al. Responses to oleic, linoleic and -linolenic acids in high-carbohydrate, high-fat diet-induced metabolic syndrome in rats[J]. The Journal of Nutritional Biochemistry, 2013, 24(7): 1381–1392.

[5] POUDYAL H, PANCHAL S K, WARD L C, et al. Effects of ALA, EPA and DHA in high-carbohydrate, high-fat diet-induced metabolic syndrome in rats[J]. The Journal of Nutritional Biochemistry, 2013, 24(6): 1041–1052.

[6] PANCHAL S K, WARD L, BROWN L. Ellagic acid attenuates high-carbohydrate, high-fat diet-induced metabolic syndrome rats[J]. European Journal Nutrition, 2013, 52(2): 559–568.

[7] KRUEGER R, DERNO M, GOERS S, et al. Higher body fatness in intrauterine growth retarded juvenile pigs is associated with lower fat and higher carbohydrate oxidation during ad libitum and restricted feeding[J]. European Journal of Nutrition, 2014, 53(2): 583–597.

[8] GUBERMAN C, JELLYMAN J K, HAN G, et al. Maternal high-fat diet programs rat offspring hypertension and activates the adipose renin-angiotensin system[J]. American Journal of Obstetrics and Gynecology, 2013, 209(3): 262.e1-262.e8.

[9] GIRIKO C Á, ANDREOLI C A, MENNITTI L V, et al. Delayed physical and neurobehavioral development and increased aggressive and depression-like behaviors in the rat offspring of high-fat diet[J]. International Journal Developmental Neuroscience, 2013, 31(8): 731-739.

[10] SEMIANE N, FOUFELLE F, FERRÉ P, et al. High carbohydrate diet induces nonalcoholic steato-hepatitis (NASH) in a desert gerbil[J]. Comptes Rendus Biologies, 2016, 340(1): 26-36.

[11] HONMA K, HIKOSAKA M, MOCHIZUKI K, et al. Loss of circadian rhythm of circulating insulin concentration induced by high-fat diet intake is associated with disrupted rhythmic expression of circadian clock genes in the liver[J]. Metabolism, 2016, 65(4): 482-491.

[12] STEIN P K, SOARE A, MEYER T E, et al. Caloric restriction may reverse age-related autonomic decline in humans[J]. Aging Cell, 2012, 11(4): 644-650.

[13] HALL K, BEMIS T, BRYCHTA R, et al. Calorie for calorie, dietary fat restriction results in more body fat than carbohydrate restriction in people with obesity[J]. Cell Metabolism, 2015, 22(3): 427-436.

[14] BREHM B J, SEELEY R J, DANIELS S R, et al. A randomized trial comparing a very low carbohydrate diet and a calorie-restricted low fat diet on body weight and cardiovascular risk factors healthy women[J]. The Journal of Clinical Endocrinology & Metabolism, 2003, 88(4): 1617-1623.

[15] National Research Council (US) Subcommittee On Laboratory Animal Nutrition. Nutrient Requirements of laboratory animals[M]. 4th rev ed. Washington, D.C.: National Academies Press, 1995.

[16] KIM E, CHOI J, KIM H. Mabolizable energy differences between values calculated using energy conversion factors and actual values determined by metabolic study of Korean starch foods[J]. Journal of Food Science, 2014, 79(4): H713-H718.

[17] CATON S J, BIELOHUBY M, BAI Y L, et al. Low-carbohydrate high-fat diets in combination with daily exercise in rats: effects on body weight regulation, body composition and exercise capacity[J]. Physiology & Behavior, 2012, 106(2): 185-192.

[18] SHEN C L, ZHU W B, GAO W M, et al. Energy-restricted diet benefits body composition but degrades integrity in middle-aged obese female rats[J]. Nutrition Research, 2013, 33(8): 668-676.

[19] MCNEEL R L, MERSMANN H J. Low- and high-carbohydrate diets: body composition differences in rats[J]. Obesity Research, 2005, 13(10): 1651-1660.

[20] CATON S J, YINGLONG B, BURGET L, et al. Low-carbohydrate high-fat diets: regulation of energy balance and body weight regain in rats[J]. Obesity, 2009, 17(2): 283-289.

[21] WANG Y, WANG P Y, QIN L Q, et al. The development of diabetes mellitus in Wistar rats kept on a high-fat/low-carbohydrate diet for long periods[J]. Endocrine, 2003, 22(2): 85-92.

[22] IBRAHIM E H, EL-AZIZ M F M A, AHMED A F, et al. Is the effect of high fat diet on lipid and carbohydrate metabolism related to inflammation[J]. Mediterranean Journal of Nutrition and Metabolism, 2011, 4(3): 203-209.

[23] HUANG D W, CHANG W C, WU J S B, et al. Gallic acid ameliorates hyperglycemia and improves hepatic carbohydrate metabolism in rats fed a high-fructose diet[J]. Nutrition Research, 2015, 36(2): 150-160.

[24] DE OLIVEIRA M C, MENEZES-GARCIA Z, ARIFA R D D N, et al. Platelet-activating factor modulates fat storage in the liver induced by a high refined carbohydrate-containing diet[J]. The Journal of Nutritional Biochemistry, 2015, 26(9): 978-985.

[25] ZHOU D, WANG H, CUI H M, et al. Early-life exposure to high-fat diet may predispose rats to gender-specific hepatic fat accumulation by programming Pepck expression[J]. The Journal of Nutritional Biochemistry, 2014, 26(5): 433-440.

[26] NAOWABOOT J, WANNASIRI S, PANNANGPETCH P. Morin attenuates hepatic insulin resistance in high-fat diet-induced obese mice[J]. Journal of Physiology Biochemistry, 2016, 72(2): 269-280.

[27] POSTIC C, GIRARD J. Contribution of de novo fatty acid synthesis to hepatic steatosis and insulin resistance: lessons from genetically engineered mice[J]. Journal of Clinical Investigation, 2008, 118(3): 829-838.

[28] 任路平. 高果糖、高脂饮食致小鼠脂肪肝机制的探讨 [D]. 博士学位论文. 石家庄: 河北医科大学, 2011.

[29] FERNANDES-LIMA F, MONTE T L R G, NASCIMENTO F A M, et al. Short exposure to a high-sucrose diet and the first 'hit' of nonalcoholic fatty liver disease in mice[J]. Cells Tissues Organs, 2016, 201(6): 464-472.

*Note: Figure translations are in progress. See original paper for figures.*