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EFFECTS OF ETHANOL ON GLYCOGEN METABOLISM

A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Biochemistry at Massey University

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ABSTRACT

The effects of alcohol on glycogen structure and metabolism in fed, starved and starved-refed animals were studied in rats, taking into account factors such as post mortem degradation, careful isolation (native glycogen), and the separate structures and metabolism of low (cytosolic) and high (lysosomal) molecular weight glycogen. These studies were performed using the technique of density gradient ultracentrifugation.

In fed animals, rats were administered doses of ethanol (intragastically) of either 2, 4, or 6 g/kg. The glycogen decreasing effect of ethanol was dose dependent. The lowest ethanol dose (2 g/kg) depleted liver glycogen content by 7-27%, while the highest dose (6 g/kg) showed 60-78% depletion. Ethanol doses of 4 g/kg and 6 g/kg decreased both low and high molecular weight glycogen almost evenly. There was slightly more low molecular weight glycogen loss than high with a 2 g/kg ethanol dose. In time course experiments, maximal glycogen depletion was observed at 90 minutes after an ethanol dose of 6 g/kg. After 24 hours, over-production of glycogen content was seen in ethanol treated rats. However, after 48 hours, liver glycogen content had returned to fed values in ethanol treated rats, although the content of low molecular weight glycogen was elevated relative to high molecular weight. .

Starvation of rats for 48 hours decreased both body weight and liver weight. The hepatic and skeletal muscle glycogen concentrations were decreased by 95% and 55% respectively. The livers of rats starved for 72 hours contained more liver glycogen than those starved for 24 hours and 48 hours. Ethanol accelerated glycogen degradation in the fed-to-starved transition. After 3 hours starvation, liver glycogen content had decreased to about half of the fed levels in ethanol treated rats. However, at 24 hours, glycogen content increased in the ethanol treated rats, to as much as twice that in the control animals. The rate and extent of depletion was greater in LMW glycogen than HMW glycogen at 6 hours and 12 hours.

Studies on the effects of ethanol on the starved-to-refed transition were undertaken using two different protocols, chow refeeding and glucose administration by intragastric intubation. On chow refeeding after 48 hours starvation, liver glycogen repletion at 5 hours was decreased by about 30% in animals treated with ethanol dose of 4 g/kg. At

longer time intervals there was no significant inhibition of glycogen resynthesis. The Inhibition of glycogen resynthesis at 5 hours was probably due both to a decrease in food intake in the treated animals and to inhibition of glycogen synthesis by ethanol. The rate and extent of resynthesis of high molecular weight glycogen was slower in treated rats than in control rats indicating that ethanol might preferentially inhibit the synthesis of high molecular weight glycogen, possibly through disruption or prevention of formation of disulphide bonds in the protein component of high molecular weight glycogen. Unlike liver, intragastric administration of 4 g/kg ethanol before chow refeeding following 48 hours starvation decreased muscle glycogen repletion until 24 hours refeeding, compared to the respective control rats.

A single dose of intragastric administration of ethanol (3.45 g/kg) 1 hour before glucose refeeding by intragastric intubation decreased liver glycogen resynthesis by between 20-40% during the 2 hours after glucose administration. Ethanol probably delayed the peak reached in liver glycogen content by either decreasing glucose absorption, by inhibiting gluconeogenesis or glycogen synthesis, or a combination of all these factors. The overall effect of ethanol in inhibiting glycogen synthesis was not, however, nearly as great as that reported previously in similar experiments.

In experiments where rats were given repeated doses of ethanol for 7 days, liver glycogen content was as much as 25 % higher in treated animals than in control animals at 24 and 48 hours after the last ethanol dose. Both low and high molecular weight glycogen had increased almost uniformly at 48 hours in the ethanol treated rats. Ethanol treatment had, however, decreased kidney glycogen content by 6-26% in the treated rats compared with the control rats, but the content of heart and muscle glycogen was not changed.

The results of this research show that ethanol-induced overproduction of glycogen was seen in fed, fed-starved and starved-refed animals and also in repeated dose experiments. This finding is potentially of great importance in exercise physiology and sports science, in helping to develop recommendations for alcohol intake during training regimes.

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LIST OF ABBREVIATIONS

ADH	Alcohol dehydrogenase
ADP	Adenosine 5' - diphosphate
Ag_2SO_4	Silver Sulphate
AlDH	Aldehyde dehydrogenase
AMP	Adenosine 5' - monophosphate
ATP	Adenosine 5' - triphosphate
° C	degrees celsius
CAC	Citric acid cycle
cAMP	Cyclic adenosine 3', 5' - monophosphate
cm	Centimetre
CoA	Coenzyme A
DNA	Deoxyribonucleic acid
Fru-2,6-P_2	Fructose 2,6-bisphophate
g	gram
GLC	Glucose
Glc-6-P	Glucose 6-phosphate
GLY	Glycogen
h, hrs	Hour
H_2O	Water
H_2O_2	Hydrogen Peroxide
KOH	Potassium Hydroxide
LAC	Lactate
MDH	Malate dehydrogenase
MEOS	Microsomal ethanol oxidising system
mg	Milligram
min	Minutes
ml	Millilitre
NaCl	Sodium chloride
NAD^+	Nicotinamide adenine dinucleotide (oxidised form)
NADH	Nicotinamide adenine dinucleotide (reduced form)
$NADP^+$	Nicotinamide adenine dinucleotide phosphate (oxidised form)
NADPH	Nicotinamide adenine dinucleotide phosphate (reduced form)
NIDDM	Non-insulin-dependent diabetes mellitus
nm	Nanometre
NMR	Nuclear magnetic resonance
PP_i	Inorganic pyrophosphate

PYR	Pyruvate
RER	Rough endoplasmic reticulum
RNA	Ribonucleic acid
TCA	Trichloroacetic acid
UDP Glc	Uridine diphosphate glucose
UTP	Uridine triphosphate
W/V	Percentage concentration weight for volume
α	Alpha
β	Beta