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HIGH CONSUMPTION OF LARD AND FRUCTOSE MODULATES LARVAL PUPATION AND STRESS RESISTANCE IN *DROSOPHILA MELANOGASTER* ADULTS

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Abstract. Obesity and metabolic syndrome are becoming the number one health problem in modern society. Unhealthy diet with sedentary life style are considered to be the main causes of obesity. Food with excessive fat and fructose play an important role here. The aim of this work was to study the effects of feeding with lard, as a source of fat, or fructose, as a source of carbohydrates, on physiological and biochemical parameters of the fruit fly *Drosophila melanogaster* Canton S. The addition of 10% lard to the basic medium containing 5% fructose inhibited pupation of Canton S larvae. Medium with 15% fructose did not affect larval pupation rate. One-week feeding with medium containing 10% lard reduced climbing activity in 9-day-old Canton S males. In addition, food with 15% lard reduced climbing activity in female flies. One-week feeding with high fructose medium (15% fructose) did not affect climbing activity of flies of both sexes. Both high calorie diets, with lard and fructose, significantly increased the resistance of males to cold stress (measured by reducing time required for recovery from chill coma), but reduced heat stress resistance (determined by faster onset in heat coma at 40°C) in both sexes. The resistance of insects to starvation was reduced on high lard medium but not on fructose one. Foods enriched with fructose or lard did not affect food consumption, body masses and triacylglyceride content and levels of low- and high-molecular thiols in 9-day-old of flies of both sexes. In addition, feeding with high lard resulted in a downward trend in lower glucose and glycogen levels, whereas high fructose had the opposite effects. Thus, foods with high fructose and lard modulated stress resistance in adult flies and may affect energy metabolism. Detailed mechanisms underlying physiological effects of high fructose and lard in *Drosophila* needs further research.

Keywords: *Drosophila*, fructose, lard, pupation, resistance to stresses.

1. INTRODUCTION

Thanks to the constant development of science and technology, human life has improved and become more comfortable. However, the availability and prevalence of high-calorie food, especially so-called fast food, are among the main causes of unbalanced nutrition and metabolic disorders such as an obesity. Today obesity has become quite a significant health problem in many countries of the world. A high-calorie food is a food rich in fats and carbohydrates. Amongst carbohydrates, consumption of fructose has been increasing during recent years. Fructose is widely used as a cheap sweetener in carbonated drinks, juices and desserts, as it is the sweetest among carbohydrates of natural origin (Hannou et al., 2018; Herman & Birnbaum, 2021; Tappy & Rosset, 2019; Taskinen et al., 2019).

Excessive intake of fructose in the liver disrupts glucose metabolism and leads to a significant acceleration of lipogenesis and triacylglyceride synthesis. The latter process is due to the high content of glycerol and acyl residues formed as a result of fructose catabolism. Fructose is absorbed in the small intestine and metabolized in the liver, where it stimulates fructolysis, glycolysis, lipogenesis and glucose formation (Taskinen et al., 2019). Thus, high fructose intake can be one of the factors in the development of metabolic syndrome (Basciano et al., 2005; Guimarães et al., 2020; Hannou et al., 2018; Taskinen et al., 2019). Markers of the metabolic syndrome are insulin resistance, intrahepatic lipid accumulation and hypertriglyceridemia, which in turn can lead to the development of type 2 diabetes and cardiovascular diseases (Taskinen et al., 2019). In case of excessive intake, fructose can enter into non-enzymatic reactions with various biomolecules (fructation), resulting in the formation of reactive carbonyl forms, which leads to the development of carbonyl stress (Semchyshyn, 2013). Diets with a large amount of fructose or animal fat (lard) increase the formation of reactive oxygen species (ROS) through the intensification of the Krebs cycle. Increased ROS production, in turn, leads to the development of oxidative stress (Bayliak et al., 2017, 2019, 2022; Emelyanova et al., 2019; García-Berumen et al., 2019; V. I. Lushchak, 2021). Carbonyl and oxidative stresses are thought to be involved in the progression of obesity and increase the risk of metabolic complications (Bayliak et al., 2019; García-Berumen et al., 2019; Semchyshyn, 2013). Therefore, understanding the mechanisms underlying fructose and lard metabolism is important.

Rodents are popular models for the study of obesity and related metabolic syndrome. High-calorie food rich in fats (Recena Aydos et al., 2019; Speakman, 2019; Tian et al., 2020) or fats with fructose (Bayliak et al., 2022; García-Berumen et al., 2019; Guimarães et al., 2020; Herman & Birnbaum, 2021) are used to induce obesity in rodents. The aim of the work was to investigate the physiological and biochemical changes in the fruit fly *Drosophila melanogaster* fed with media containing lard as a source of fat and fructose as a source of carbohydrates. *Drosophila* is often used as a model to study obesity and other metabolic diseases. This is explained by a number of reasons. First, the fly has tissues, organs and systems similar to those involved in human obesity. In addition, in Drosophila, obesity and related complications develop under the influence of excessive caloric intake, just as in humans (Musselman & Kühnlein, 2018). Also, about 75% of disease-causing genes in humans have homologous forms in *Drosophila* (Bayliak et al., 2019; Reiter et al., 2001).

2. MATERIALS AND METHODS

2.1. Maintaining of D. melanogaster

D. melanogaster flies of Canton S line (wild type) were used for the study. The flies were obtained from the collection of Indiana University, Bloomington Stock Center (USA).

Fly cultures were maintained at 25 °C, 55-60% humidity in a 12-h dark/light cycle in 250 ml glass bottles with 25 ml of medium containing 5% sucrose, 5% dry yeast, 6.1% corn grits, 1% agar and 0.18% methyl paraben to inhibit mold growth. In these bottles, eggs hatched, larvae developed, pupated and eclosed.

The flies that were grown on the control medium until two days old were transferred to the control and experimental media. Control medium contained 5% fructose, 5% yeast, 1% agar, 1% nipagin was used. The experimental media contained additionally 10% lard, or 15% fructose instead 5% fructose. Flies stayed on these media until they reached the age of nine days.

2.2. Determination of pupation rate

The dynamics of fly development was assessed by counting the number of pupae once a day, starting from 4 to 10 days after egg laying. The number of pupae was expressed as a percentage of eggs; the number of laid eggs was taken as 100%. After hatching, two-day flies were used for further experiments (Bayliak et al., 2018).

2.3. Determination of climbing activity, resistance to cold stress and starvation

Climbing activity was measured by registering the number of flies that climbed at least 5 cm upwards on the wall of glass a vial within 20 seconds after gentle tapping to the bottom of the vial (Bayliak et al., 2016). Resistance to cold stress was assessed by recording recovery time from chill coma, induced by placing flies at 0 °C for 15 min. To test resistance to starvation, 10 flies of the same sex were transferred to glass vials containing 1.25 mL of 1% agar and plugged with cotton to prevent desiccation. The number of dead flies was registered at defined time points until all flies died, and values were expressed as the percentage of flies that survived (Bayliak et al., 2018).

2.4. Food consumption

The amount of food consumed was determined by an indirect method by measuring the amount of blue food dye (E133) consumed with food. Flies were kept on experimental media with the addition of E133 dye for 1.5 hour. After that, flies were anesthetized and transferred to cryotubes for freezing and weighed to determine the body mass of flies. Frozen flies were homogenized in 50 mM KH_2PO_4 and centrifuged for 10 min at 13000 rpm. Then the optical density of the resulting supernatants was determined at λ=629 nm at which the dye has a maximum absorption (Bayliak et al., 2018).

2.5. Determination of the concentration of triacylglycerides (TAG), glucose and glycogen

Levels of glucose and triacylglycerides (TAG) were measured using diagnostic kits from Filicit-Diagnostics Ltd. (Dnipro, Ukraine) following the manufacturer's instructions. To determine glycogen, it was cleaved by amyloglucosidase (Sigma-Aldrich, #10115; 0.56 U/μL) for 2 h at 37 °C. After incubation, glucose content of the samples was measured. Glycogen content was calculated by the difference between glucose content after and before incubation with amyloglucosidase (Bayliak et al., 2020).

2.6. Determination of thiol groups

The method is based on the reaction of thiols with 5,5'-dithiobis-2-nitrobenzoic acid (DTNB), resulting in the release of a substance that absorbs light with a maximum at 412 nm. For determination of low-molecular mass thiols (L-SH), supernatants were treated immediately after centrifugation with 10% trichloroacetic acid to precipitate protein, centrifuged and the supernatant saved. Supernatants were obtained by homogenization of frozen flies in lysis buffer (50 mM KPI, pH 7.0, 1 mM phenylmethylsulfonyl fluoride, 0.5 mM EDTA) at a ratio of 1:10 (w/v). After homogenization, the samples were centrifuged for 15 min at 4 °C at 16,000 g (Bayliak et al., 2020). Obtained supernatants were used for the experiment.

2.7. Statistical analysis

Statistical analysis was carried out using Microsoft Excel and GraphPad_Prism_.8.0.1.244. The results are presented as the mean ± SEM of at least three replicates. One-way ANOVA followed by

Dunnet's t-test was used to compare the mean values and identify significant differences between them. The criterion of significant difference is P≤0.05.

3. RESULTS AND DISCUSSION

3.1. Effects of high lard and fructose on pupation rate of fruit fly

Pupation rate is one of the important parameters for evaluating development of Drosophila. Previous studies on *Drosophila* have shown that high concentrations of carbohydrates in the medium caused a delay in pupation (Rovenko et al., 2015) and shortened lifespan of fruit flies (O. V. Lushchak et al., 2012). In addition, it was demonstrated a shortening of the lifespan of fruit flies on a medium with a high fat content (Driver & Cosopodiotis, 1979). Therefore, firstly, we tested how food containing 10% lard and 15% fructose would affect the pupation rate of D. melanogaster Canton S line.

Fig. 1 shows the pupation rate of fruit fly on experimental media. Control medium contained 5% fructose as an energy source. One experimental media contained 5% fructose and 10% lard (L10) and another contained 15% fructose (F15). As we can see, the larvae pupated most slowly on the medium with 10% lard. In particular, the first pupae on 10% lard appeared on the 5th day while on the control medium larvae began to pupate on the 4th day. Larvae were fully pupated at 5th day and the 7th day on control medium and lard-containing medium, respectively. However, a high concentration of fructose (15%) did not change the rate of pupation compared to the control, and the first pupae on this medium appeared on day 4, and the maximum of pupation was observed on day 6.

Thus, the presence of 10% lard in the medium inhibited the pupation, whereas 15% fructose did not affect pupation in Canton S larvae as compared with the control media with 5% fructose.

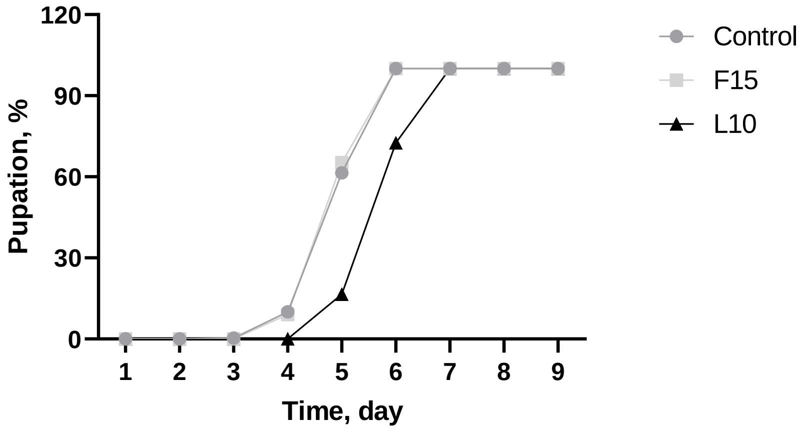

Fig. 1. Pupation rate of D. melanogaster Canton S on control medium and media with 10% lard (L10) and 15% fructose (F15), n=3

3.2. Climbing activity of D. melanogaster

Induced locomotor activity measured as a climbing activity is an important indicator of fly mobility. Climbing activity is based on the phenomenon of negative geotaxis, i.e. upward movement of insects on cylinder wall after shaking down. It is believed that the locomotor activity of insects decreases with age (De Nobrega & Lyons, 2020; Ratliff et al., 2015). Also, this parameter is used to study disorders of the nervous system that can occur under oxidative stress (Vitushynska et al., 2015). The latter is one of the manifestations of obesity and develops due to an increase in ROS generation as a result of increased intensity of metabolic processes (Rovenko et al., 2012) .

Climbing activity was measured in 9-day-old *Canton S* adult flies, which consumed media with fructose and lard for one week starting from age of two days after eclosion. In this experiment, in addition to 10% lard, a lard concentration of 15% was also used. Six replicates were conducted. The results of the measurement are shown in Fig. 2.

We observed that high concentration of fructose (15%) did not affect the locomotor activity of fruit flies. In males fed medium with 10% lard, the climbing activity was by 38% reduced compared to the control group, but medium with 15% lard did not affect climbing activity in male flies. Females showed a marked decrease (by 26%) in locomotor activity on the medium with 15% lard. Thus, the addition of lard at a concentration of 10% to the medium reduced the induced motor activity in males, and 15% lard reduced this parameter in *Canton S*.

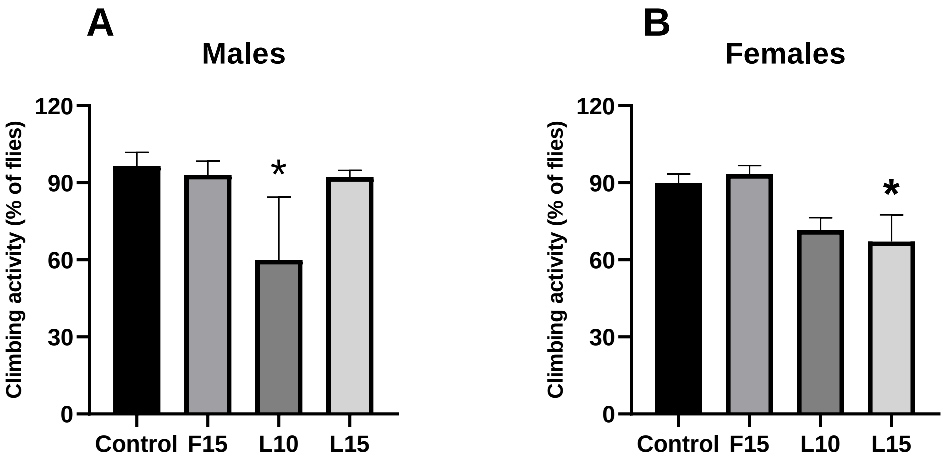

*Fig. 2. Induced locomotor activity of nine-day-old D. melanogaster Canton S maintained on control medium and media with 15% fructose (F15), 10% (L10) and 15% (L15) lard. * - significantly different from the corresponding values in the control group, P≤0.05, n=6 (10 flies in each repeat).*

3.3. Cold and heat stress resistance

Drosophila belongs to cold-blooded animals. When exposed to low and high temperatures, flies can lose their activity and fall into a coma. If the temperature changes are not prolonged, the insects can recover from coma and continue their normal life. Adaptive capabilities of insects are considered better if they restore their vital activity faster (Bayliak et al., 2017).

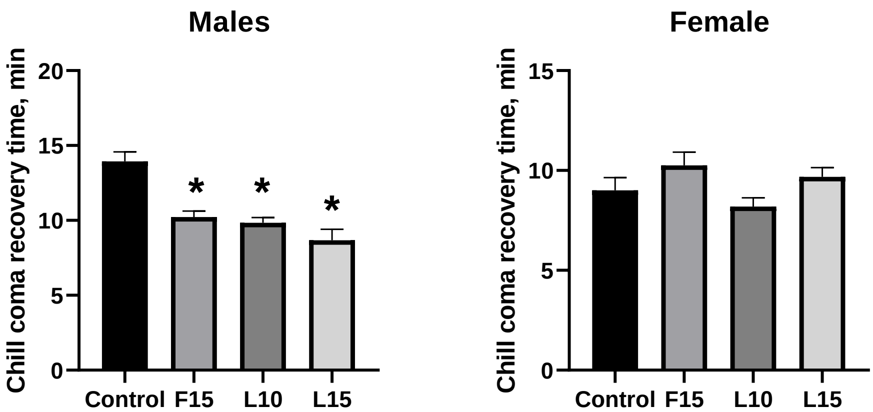

*Fig. 3. Cold stress resistance of nine-day-old D. melanogaster Canton S maintained on control medium and media with 15% fructose (F15), 10% (L10) and 15% (L15) lard. Resistance to cold stress was determined by recording the time required to recover from cold coma * - significantly different from the corresponding values in the control group, P≤0.05, n=4 (10 flies in each repeat).*

Because it was reported that that fruit flies on a diet high in fat (coconut oil) showed decreased viability at low temperatures (Heinrichsen & Haddad, 2012), we decided to test the effects of feeding with high concentrations of fat and fructose on fly resistance to cold stress.

Fig. 3 shows the resistance to cold stress of nine-day-old *Canton S* fed with control and experimental media. As we can see, different concentrations of fructose and lard did not significantly change the time of recovery from cold coma in females. However, males on all experimental media showed a significant reduction in recovery time from cold coma, in particular most of the control insects and insects from the experimental groups came out of chill coma at 14 minutes and 10 minutes, respectively, after the start of recovery to temperature of 25 °C.

Fig. 4 shows the time of falling into a thermal coma.

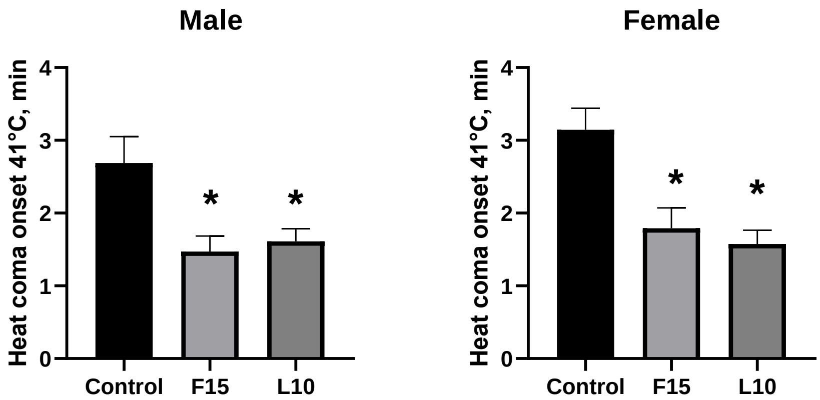

*Fig. 4. Heat stress resistance of nine-day-old D. melanogaster Canton S maintained on control medium and media 15% fructose (F15) and 10% lard (L10). * - significantly different from the corresponding values in the control group, P≤0.05, n=4.*

On experimental media flies of both sexes fell into coma faster than on control media. Thus, insects that consumed the basic medium with 5% fructose fell into a thermal coma on the third minute of observation, and those that were on high concentrations of fructose and lard lost their activity by the second minute of the test.

3.4. Resistance to starvation

In fruit flies, resistance to starvation is thought to be influenced by the ratio of proteins: carbohydrates in the diet. The lower this ratio is, the higher is resistance to starvation (Lee & Jang, 2014). There is also evidence that w^{1118} flies reared on a high fat diet (coconut oil) were more resistant to food deprivation and survived longer (Heinrichsen & Haddad, 2012). Thus, we decided to test how maintenance on media with lard and fructose at different concentrations could affect starvation resistance in *Canton S* flies.

Resistance to starvation was determined in 21-day-old flies of *Canton S* line, which were on experimental media. Fig. 5.A and 5.B show the results of starvation survival of males and females, respectively. Males of all groups had lower resistance to starvation than females, especially males on medium with 10% lard were significantly sensitive to starvation than the same females. Males fed with high fructose (F15) and lard (L10) died during 24 hour 15 hours, respectively under transferring to starvation conditions as compared with the control group. Resistance to starvation in females was much higher. Females fed high fructose and high lard survived during 130 hours and 90 hours, respectively. Thus, *D. melanogaster* females are more resistant to starvation than males that is consistent with previous studies (Lylyk et al., 2018).

Feeding with 10% lard inhibited the survival of both males and females under starvation conditions. In our study, the protein concentration was unchanged (yeast 5%), only the percentage of carbohydrates was changed (*e.g.*, control medium contained 5% fructose, and one experimental medium contained 15% fructose). Taking into account previous study (Lee & Jang, 2014), we expected that flies fed with the medium with 15% fructose would show higher resistance to starvation compared to the control (fructose 5%). But, 15% fructose did not significantly affect starvation survival in males and females as compared with the control group that not corresponds our expectations.

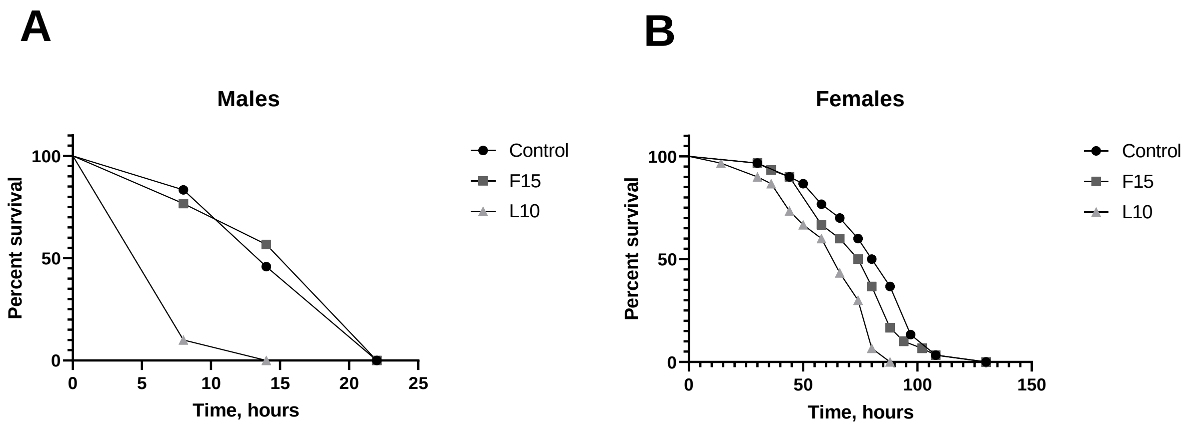

Fig. 5. Resistance to starvation of 21-day-old D. melanogaster Canton S maintained on control medium and media with 15% fructose (F15) and 10% lard (L10), n=3 (10 flies in each repeat).

3.5. Body mass and food consumption

Fig. 6 shows the results of determining the body masses of flies fed with experimental media. As we can see, the body mass did not differ in either males or females on the experimental media. Therefore, the high-calorie diets did not affect the body of nine-day-old *Canton S* flies of both sexes. It is known from previous studies that females of *Canton S*, which were fed on medium with high fructose content (10%, 20%) showed an increase in body mass (Rovenko et al., 2015), but this difference was fixed only between flies consumed low caloric food (0.25% carbohydrates) and high caloric food (10 and 20% carbohydrates). In our experiment, control food contained 5% fructose, and it seems that this media was enough caloric for flies, or maybe the absence of difference in body masses on control and high caloric media might be due to difference in food consumption. To check this assumption, we measured intensity of food consumption on the studied media.

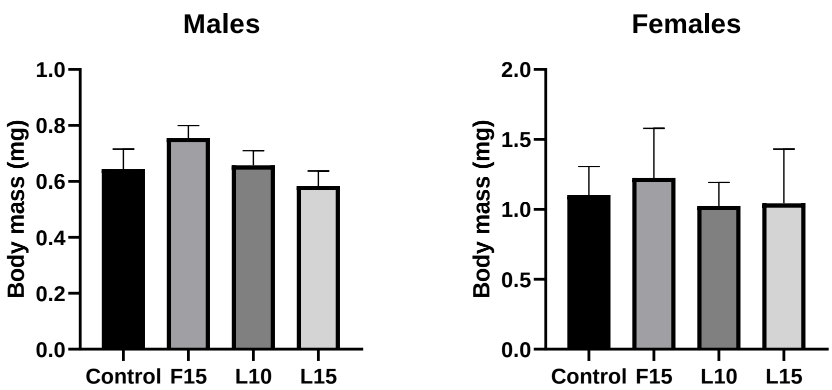

Fig. 6. Body mass of nine-day-old D. melanogaster Canton S maintained on control medium and media with 15% fructose (F15) and 10% (L10) and 15% (L15) lard, n=7-9 (10 flies in each repeat)

Determination of food consumption is an important indicator of behavioral reactions, nutrition and drug intake in fruit flies (Wong et al., 2009). When the level of carbohydrates in the diet increases, flies consume less food due to the reduced yeast (protein) content. However, on a diet with fructose, flies were shown to consume about 25% more food than on glucose-containing food (Rovenko et al., 2015).

Food consumption was determined in two-day-old *Canton S*, which were grown on yeast-sucrose medium (5% sucrose) and then transferred on experimental media for 1.5 h. Fig. 7 demonstrates that both males and females had similar intensity of food consumption, regardless of type of food. Thus, at starting of feeding with high-calorie diets two-day-old *Canton S* flies did not differ in the intensity of food consumption. At the same time, experimental males and females tended to consume less and more, respectively, as compared with the control group.

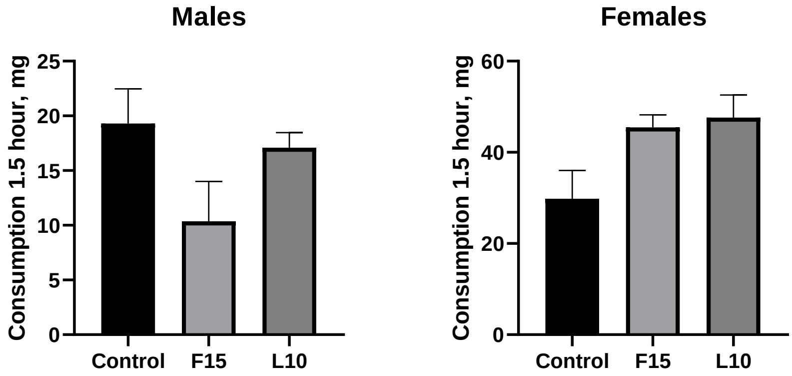

Fig. 7. Food consumption by two-day-old D. melanogaster Canton S on control medium and media with 15% fructose (F15) and 10% lard (L10), n=3 (10 flies per repeat).

3.6. Glucose, glycogen and TAG content

Glucose is one of the important sources of energy circulating in *Drosophila* hemolymph. Increased concentration of carbohydrates in food increases the level of circulating glucose (Chatterjee & Perrimon, 2021). Previous studies have shown that excessive consumption of diets enriched with fructose and glucose leads to hemolymph hyperglycemia (Musselman et al., 2019) and to higher levels of body glucose and glycogen, a reserve form of glucose, in *Drosophila* (O. V. Lushchak et al., 2021). Therefore, we measured levels of free glucose and glycogen in the bodies of flies maintained on experimental diets. The glucose content is shown in Figs. 8.A and 8.B.

As we see, high fructose-fed males showed a tendency to lower whole body glucose levels, whereas fructose-fed females had a tendency to higher glucose levels. The glucose level was by 40% lower in males fed with on medium containing 10% lard compared to the control group. No significant differences in glucose levels were observed between control and lard-fed females.

Excess energy that *Drosophila* receives from food, as in mammals, is stored as glycogen and triacylglicerides (TAG). A high sugar diet is known to stimulate the expression of glycogen synthase, an enzyme involved in glycogen synthesis (Chatterjee & Perrimon, 2021; Garrido et al., 2015). Given that high concentrations of carbohydrates (15% fructose) were also used in our study, it was expected that glycogen levels would also be elevated.

Figs. 8.C and 8.D show the glycogen content of these flies. Glycogen levels do not change significantly in either males or females on both fructose and lard media, but glycogen levels tended to be lower in lard-fed flies females. Thus, flies maintained on 10% lard showed to a tendency to have lower both glucose and glycogen levels.

It is believed that the levels of TAG and total lipids increases on media high in fats (Baenas & Wagner, 2022) and in carbohydrates, in particular fructose (Rovenko et al., 2015). Studies with flies of the w^{1118} line, confirmed the increase in TAG levels in flies on the medium with high fat content (coconut oil) (Diop et al., 2017; Heinrichsen & Haddad, 2012).

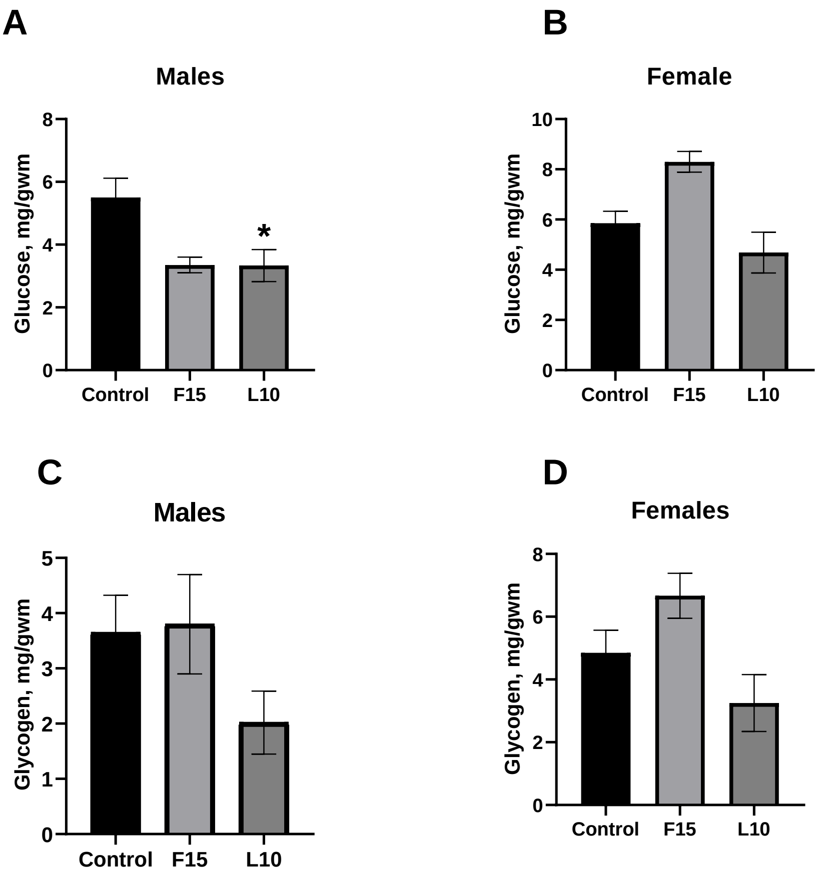

*Fig. 8. Glucose and glycogen content in nine-day-old D. melanogaster Canton S maintained on control medium and media with 15% fructose (F15) and 10% lard (L10). * - significantly different from the corresponding values in the control group, P≤0,05, n=3-5.*

In our experiment, a week of exposure to the experimental media with high fructose or high lard did not change the levels of TAG in either females or males compared to the respective controls.

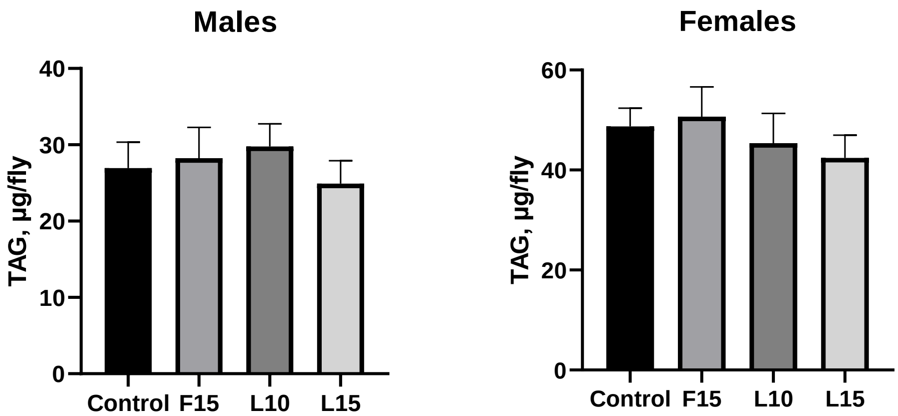

Fig. 9. TAG content in nine-day-old D. melanogaster Canton S maintained on control medium and on media with 15% fructose (F15), 10% (L10) and 15% lard (L15), n=9.

It should be noted that females have significantly higher levels of body TAG, than males. It is known that the fruit fly has sexual dimorphism between females and males. One of its manifestations is that females have more fat cells in the whole body compared to males (Diop et al., 2017). Therefore, it can explain higher level of TAG in females compared with males.

3.7. Low and high molecular mass thiols content

Consumption of carbohydrates or fats in high amounts increases the intensity of metabolism, as well as respiratory activity of the electron transport chain of mitochondria (Bayliak et al., 2019). This leads to an increase in ROS production and causes oxidative stress (Rovenko et al., 2015). Also, activation of antioxidant defense may occur. Thiols are antioxidant compounds that protect cells from free radicals and are markers of oxidative stress (Munday, 1989). We measured the content of low- and high-molecular mass thiols in flies fed with high-calorie media. Fig 10 shows the content of low molecular mass and high molecular mass thiols in males and females Canton S.

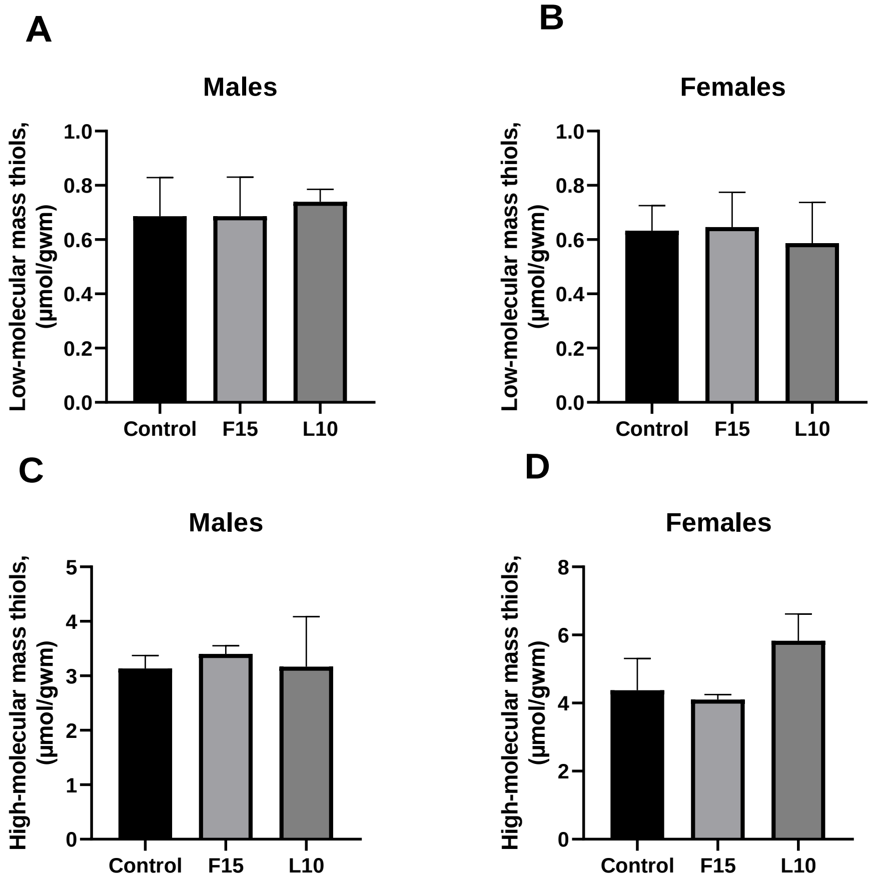

Fig. 10. Content of low and high molecular mass thiols in nine-day-old D. melanogaster Canton S flies on control medium and media with 15% fructose (F15) and 10% lard (L10), n=3.

The content of high and low thiol groups did not change when the fly consumed 15% fructose and 10% lard, compared to the control (5% fructose). Earlier it was shown that with increasing concentration of carbohydrates (sucrose) in the media, the level of high molecular mass (protein) thiols also increased in the body of flies (Rovenko et al., 2015). However, another study showed that the level of high molecular mass thiols did not depend on the concentration of sucrose in the medium, and the level of low molecular mass thiols decreased with increasing carbohydrate concentration (Strilbytska et al., 2022).

In general, in our experiments, flies were kept on high-calorie media only for a week. Therefore, obviously, this time is not enough for the development of the expected changes.

4. Conclusions

Our results demonstrate an inhibitory effect of lard at high concentrations but not fructose on development of D. melanogaster Canton S slowing down the pupation of larvae. Feeding of adults flies with lard-based food but not with high fructose-based affected locomotor activity by reducing climbing activity of males. Both high calorie diets (fructose and lard-based ones) significantly increased the resistance to cold stress (in males) but reduced resistance to heat stress (in both sexes). In addition, lard-based food decreased starvation resistance in both sexes. Feeding with high lard resulted in a downward trend in lower glucose and glycogen levels, whereas high fructose had the opposite effects. Both high-calorie diets did not affect triacylglyceride and thiol levels in flies of both sexes. Detailed mechanisms underlying physiological effects of high fructose and lard in *Drosophila* needs further research.

Conflict of interest

The authors declare that they have no conflict of interest.

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Гурза Вікторія, Бутенко Наталія, Дем'янчук Олег, Балацький Віталій, Деркачов Віталій, Лилик Марія. Споживання їжі з високим вмістом смальцю або фруктози модулює заляльковування личинок та стресостійкість у дорослих особин Drosophila melanogaster. *Журнал Прикарпатського університету імені Василя Стефаника*, **9** (4) (2022), 42–55.

Ожиріння та метаболічний синдром, стають проблемою номер один для здоров'я сучасного суспільства. Неправильне харчування та сидячий спосіб життя є одними з основних причин ожиріння. Надмірний вміст жиру та фруктози, як найдешевшого підсолоджувача, у харчовому раціоні людини відіграють тут не останню роль. Метою цієї роботи було дослідити вплив смальцю, як джерела жиру, та фруктози як джерела вуглеводів на фізіолого-біохімічні показники в організмі плодової мушки *Drosophila melanogaster* лінії Canton S. Додавання 10% смальцю до базового середовища, яке містило 5% фруктози, інгібувало заляльковування личинок плодової мухи, тоді як середовище з 15% фруктози не впливало на швидкість заляльковування. Утримування на середовищі з 10% смальцю протягом одного тижня знижувало індуковану рухову активність у 9-денних самців лінії Canton S. Також, середовище з 15% смальцю знижувало індуковану рухову активність у самок. Тижневе годування високофруктозним середовищем (15% фруктози) не впливало на індуковану рухову активність у мух обох статей. Висококалорійні дієти обох типів, зі смальцем та фруктозою, суттєво підвищували стійкість самців до холодового стресу (визначену за зменшенням часу, необхідного для відновлення з холодової коми), але знижували стійкість до теплового стресу (визначену за зменшенням часом впадання у теплову кому) в обох статей. Утривування на середовищі з 10% смальцю але не з 15% фруктозою знижувало стійкість комах до голодування. Їжа з високою концентрацією фруктози або смальцю не впливала на споживання їжі, масу тіла мух, вміст триацигліцеридів, низько – і високомолекулярних тіолів у 9-денних мух обох статтей. Окрім того, вміст глюкози та глікогену демонстрував тенденцію до зниження у мух на середовищі з високим вмістом смальцю, тоді як на середовищі з високим вмістом спостерігалися протилежні ефекти. Таким чином, їжа з високим вмістом фруктози та смальцю модулювала стресостійкість у дорослих мух та могла впливати на енергетичний обмін у мух. Детальні механізми, що лежать в основі фізіологічних ефектів їжі з високим вмістом фруктози та смальцю у дрозофіли, потребують подальших досліджень.

Ключові слова: дрозофіла, фруктоза, смалець, лялькування, стійкість до стресів.