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The influence of plant-based diet and level of oestrogen on life satisfaction of women

– Results of a pilot study –

Pinar Şengül[a] **& Erich Kasten**[b]

[a] Birkbeck, University of London. Department of Psychology. Malet Street, Bloomsbury, London WC1E 7HX, Great Britain, Email: physicspinar@gmail.com

[b] Medical School Hamburg; Medical University and University of Applied Sciences. Am Kaiserkai 1, D-20457 Hamburg, Germany, Email: EriKasten@aol.com

Abstract

Previous studies have shown that people benefit more from vegetarian or vegan diets than from an omnivorous diet, not only in physical but also in mental health. Studies have also reported substantial evidence that particular disorders can be triggered by preferred food choices. For example, consumption of animal products increases the intake of arachidonic acid which can induce depressive moods. On the other hand, nutrition can have positive effects, e.g. polyunsaturated N-3 fatty acids have several somatic health benefits not only on cardiovascular diseases, but also on depression. Similarly, a diet with a high content of tryptophan (a serotonin predecessor) can change mood by altering the synthesis of different neurotransmitters. In this pilot study, (i) omnivores (n=45), (ii) vegetarians (n=13) and (iii) vegans (n=7) were compared for their levels of satisfaction in everyday life, as measured on the *Oxford Happiness Scale*. The effect of oestrogen was analysed as a confounding variable. Between the three styles of nutrition, only small differences were found. All groups achieved an average of more than 4 points on a 6-stage Likert-scale (1=not happy, 6 = very happy), which lies in the range of moderately happy. The mean score of all three groups was 4.30 ±0.84. The difference between the omnivore, (4.23 ±0.69) and the vegetarian groups, (4.29 ±1.24) was very small, but the vegan group achieved a score well above 5, (5.20 ±0.17). In an ANCOVA, the effect of nutrition style on happiness was close to being significant, [p=0.066]. In addition, estimated oestrogen level had significant effects on satisfaction in everyday life, [p=0.047]. Conclusion: Further research on a larger sample is justified to determine if life satisfaction is influenced by nutrition style when controlled for oestrogen levels.

Key-words: veganism, vegetarian, omnivores, nutrition style, diet, oestrogen, happiness, life satisfaction

Introduction

Lack of life satisfaction is closely linked to depression and other emotional disorders. This article focuses on the relationship between diet, onset of emotional disorders, and experimental data that suggest that proper nutrition may have an essential function in explaining vitality and avoiding depression.

Mental illness, e.g. depression, anxiety or bipolar disorder, not only leads to individual suffering, but also to a substantial social and economic burden (Davison & Neale, 1998). The treatment of mental disturbances is currently dominated by pharmacotherapy (e.g., antidepressants) and psychotherapy, (e.g., cognitive behavioural therapy); however, additional strategies are needed. There is now consistent evidence that a deficient diet is a risk factor for mental illness (D'Andreamatteo, 2016; Owen & Corfe, 2017; Marx et al., 2017). Nutrition is widely known to be related to physical health (Atkinson et al., 2015; Dinu et al., 2017), but its psychological aspects are often neglected. Many health care professionals are now aware that food patterns often precede psychopathological developments such as depression (Rao, 2008); malnutrition can impair the quality of life and lead to psychopathological disturbances (Ghimire et al., 2018). Marx and co-authors (2017) published an overview of the nutritional-psychiatry field. They found that neurobiological mechanisms are modulated by the type of diet. According to these authors, potential biological pathways, which are related to mental disorders, include inflammation, oxidative stress, the gut microbiome, epigenetic modifications and neuroplasticity. Consistent epidemiological evidence, particularly for depression, suggests an association between measures of diet quality and mental health (Sánchez-Villegas, 2018). Dietary interventions in clinically diagnosed populations can provide significant clinical benefits (Koopman et al., 2017; Opie et al., 2017). Furthermore, regular intake of "nutraceuticals", which are products to provide extra health benefits (as e.g., additional vitamins, minerals, enzymes, amino acids, n-3 fatty acids, folate, S-adenosylmethionine, N-acetyl cysteine and probiotics) are promising avenues for future research (Marx et al, 2018).

Several studies have shown a connection between depression and inflammation; depressive patients have an increased risk for inflammations and, on the other hand, patients with chronic inflammation often develop depression (Kasten, 2011a, b; 2015). Nutrition can have positive effects on inflammatory processes. According to Siriwardhana and co-authors (2012) polyunsaturated N-3 fatty acids (n-3 PUFA) have several somatic health benefits (e.g. on high blood pressure and other cardiovascular diseases, prevention of cancer, premature aging and arthritis), but in addition they have anti-depressive effects. The n-3 PUFAs have antioxidant effects and act by pro-inflammatory antagonization of the Prostaglandins (PGEs). Due to this reaction they even have an anti-inflammatory impact on the activation of the nuclear factor K_B, which is an inducer of proinflammatory cytokine production (e.g. interleukin-6 or tumour necrosis factor-α). Deacon et al (2017) reviewed the aetiology and pathophysiology of depression, and explored the role of such omega-3 polyunsaturated fatty acids (n-3 PUFA). These authors suggested that fatty acids are critical for the development and functioning of the central nervous system not only in childhood. Thus, increasing evidence from epidemiological, laboratory, and randomized placebo-controlled trials suggests that deficiency of dietary n-3 PUFAs may contribute to the development of mood disorders, and supplementation with n-3 PUFAs may provide a new treatment option.

Mantzorou et al. (2018) found in an investigation of more than 2,000 elderly people that a high prevalence of malnutrition was directly associated with cognitive impairment and depression. Opie and co-authors (2017) gave key dietary recommendations for the prevention

of depression based on current published evidence. These consist of: (1) follow 'traditional' dietary patterns, such as the Mediterranean, Norwegian, or Japanese diet; (2) increase consumption of fruits, vegetables, legumes, wholegrain cereals, nuts, and seeds; (3) include a high consumption of foods rich in omega-3 polyunsaturated fatty acids; (4) replace unhealthy foods with wholesome nutritious foods; (5) limit intake of processed-foods, 'fast' foods, commercial bakery goods, and sweets. Existing evidence suggests that a combination of healthy dietary practices may reduce the risk of developing depression.

Data support the role of fatty-acid status in depression vulnerability and indicate the above-mentioned role for omega-3 fatty acids in the prevention of inflammation-induced depression (Lotrich et al, 2013). Omega-3 fatty acids have been linked to healthy aging throughout life. The omega-3 fatty acids Eicosapentaenacid (EPA) and Docosahexaenacid (DHA)have been associated e.g. with foetal development, cardiovascular function, and Alzheimer's disease (Swanson et al., 2012; Che et al., 2018). In medication-free patients suffering from major depression, Ter Horst and co-authors (2018) found significant differences between patients versus controls in relation to their fatty acid status. Because omega-3 fatty acids are not efficiently synthesized in humans, it is necessary to obtain adequate amounts through the diet.

Omega-3 (earlier called vitamin F) is a subgroup of the unsaturated omega-n fatty acids. They are contained in algae and plants. Fish absorb most of the fatty acids EPA and DHA through consumption of algae, but can also synthesize them themselves. Omega-3 fatty acids (but not much if any preformed DHA and EPA) are found in various vegetable oils, e.g. chia oil (60%), linseed oil (60-70%); perilla oil (60%), rapeseed oil (10%), soybean oil (8%), walnut oil (13%).Fish such as Atlantic salmon (1.8%), sardine (1.4%), herring (1.2%), mackerel (1.0%) contain the preformed forms. According to Harris (2007) a daily intake between 100 mg and 600 mg EPA and/or DHA per day is required.

Koopman and El Aidy (2017) found that several neurobiological alterations have been linked to the development of depression. They suggested that a balanced microbial community, modulated by diet, is a key regulator of the host physiology. According to these authors, it seems likely that gut microbiota plays a role in depression. Kelly et al. (2016) find that depression is regularly associated with decreased gut microbiota variety. They transplanted microbiota from depressed patients to microbiota-depleted rats showing that this led to typical symptoms of depression in the animals, including anhedonia and anxiety-like behaviours. Wong and co-authors (2018) focused on the current literature on vegan diets and their unique impact on gut microbiota, and reported benefits for gut microbiota. Cannon (2015) cited a story of a man named Tom Spector who ate only ultra-processed ‘fast food’ for ten days. Analysis found that his gut microbial ecology had been devastated, with a massive loss of protective bacteria. Cannon warned, that “junk food” as well as intake of antibiotics have negative effects on microbiota and consequently on mood.

The finding that some types of mental illnesses depend on deficits of nutrition suggests that mood can be improved by consuming certain foods which are rich in the above-mentioned nutrients. Essential fatty acids were the most efficient mood enhancers followed by carbohydrates and proteins. Riachi (2016) found that a breakfast comprised of walnuts, pistachios, olives, avocados and fruits that contain polysaccharides, forms a good foundation for a happy day, while protein-rich meals (eggs, dairy, pork etc.) did not result in heightened mood levels. Consumption of glucose has a small effect in inducing a brief sense of well-being (Wen et al., 2018). This is caused by the release of neurotransmitters (e.g., dopamine and ß-endor-

phin) as part of the innate reward-system for eating sugar, the most important source of energy for cells (Koekkoek, 2017).

Food can have an effect on our emotions (Wallin & Rissanen, 1994). Many affective disorders have strong correlations with eating disorders, for example in patients suffering from anorexia nervosa (Gero, 1952; Davison & Neale, 1998). Patients suffering from seasonal affective disorder often have an intense hunger for sweets (Berman et al, 1993). Dysfunctions of the serotonergic system can result in various eating disorders such as binge eating or anorexia nervosa. The serotonergic system stimulates the hypothalamus and sends signals to inhibit hunger when satiety is felt (Beutler et al., 2017). If serotonin is deficient in the central nervous system, these signals do not reach the hypothalamus, resulting in continued eating, which can result in obesity. Depression may be induced by insufficient tryptophan, which is converted into serotonin in the body (Kaluzna-Czaplinska et al., 2017). Pineapples, tofu and nuts are rich in tryptophan. It is recommended that clinical psychologists enquire about eating habits and preferred foods of the patient before diagnosing any kind of illness, since the mental disturbance may be caused or influenced by dysfunctional eating habits. Therefore, information about the eating behaviour of a patient can help to develop a tailored treatment for mental disorders (Wallin & Rissanen, 1994).

Omnivorous diets often include high levels of arachidonic acid which causes cell death through the mitochondrial permeability transition (Scorrabno et al., 2001) and is associated with an increased risk of depression. Brain serotonergic signalling is related to arachidonic acid-releasing calcium-dependent phospholipase. Disturbed serotonergic neurotransmission has been reported in a rat model of depression, suggesting that brain arachidonic acid metabolism may be elevated. (Blanchard et al., 2015).

Several other studies found that high levels of EPA and DHA are correlated with more positive feelings and prevent depression (Freeman et al, 2006; Ferrucci et al., 2006; Hibbeln, 2002; Nemets et al., 2006; Robles, et al., 2005; Smuts et al., 2003; Sublette et al., 2006). However, vegetarians who consumed relatively less EPA still experienced better mood states. In a 2-week trial, Beezhold (2012) reported that vegans experienced the highest mood followed by pescatarians (who consume fish and eggs but no meat) and lastly omnivores. As stated above, omega-3 fatty acids need not be obtained from fish as they are found in many vegetable foods as ALA which can be converted to EPA and DHA in the human body.

Another study investigated 138 healthy men and women with different diet styles (Beezhold 2010), and a vegetarian diet was found to be associated with elevated mood states in contrast to omnivorous diets. Despite low intake of EPA and DHA, vegetarians achieved lower scores in tests which examine subjective levels of stress e.g. in POMS (Profile of Mood States), which is a standard validated psychological test formulated by McNair et al. (1971). The questionnaire contains 65 words/statements that describe subjective feelings. The test requires the participant to indicate for each word or statement how often they have experienced the feeling in the preceding week including the day of the test. It was found that females had higher POMS-scores than men, which, as one of many other factors, may be related to unstable oestrogen levels in the blood circulation. Moreover, the scores on the psychological tests were positively related to omega-3 fatty acids, arachidonic acid, and inversely associated to alpha linoleic acid (ALA) and linoleic acid (LA), which is consistent with plant-based diets that are low in omega three acids and arachidonic acid, and high in ALA and LA.

Most of the recent psychological studies concentrating on the effects of diet on mood have neglected the differences between vegan, vegetarian and omnivorous eating habits (e.g.: Clarys et al., 2014). For example, vegan and vegetarian participants are often included in

one group, because they avoid meat consumption (e.g.: Piccoli et al. 2015, Attini, 2016). But omnivores and vegetarians both consume animal protein (e.g., in milk products). According to Matta and co-authors (2018) the association between depressive symptoms and vegetarian diets is controversial. Their study examined the association between depressive symptoms and vegetarian diets while controlling for potential confounds. Among 90,380 subjects from the population-based Constances cohort, depressive symptoms were defined by a score ≥19 on the Centre of Epidemiologic Studies-Depression (CES-D) scale. Diet types (omnivorous, pesco-vegetarian, lacto-ovo-vegetarian and vegan) were determined using a food frequency questionnaire. Associations between depressive symptoms and diet were estimated through logistic regressions adjusting for socio-demographics, other foods, alcohol and tobacco consumption, physical activity and health-related concerns; specificity analyses considered the exclusion of any other food group. Depressive symptoms were associated with pesco-vegetarian and lacto-ovo-vegetarian diets in multivariable analyses (odds-ratio: 1.43 and 1.36, respectively), especially in cases of low legume intake (p for interaction < 0.0001), as well as with the exclusion of any food group (e.g., 1.37, 1.40, 1.71 for meat, fish and vegetable exclusion, respectively). Regardless of food type, the odds-ratio of depressive symptoms gradually increased with the number of excluded food groups (p < 0.0001).

Worldwide, the prevalence of depression in women is significantly greater than in men (Davison & Neale, 1998). Available data suggest that oestrogen, or its absence, is strongly implicated in the regulation of mood and behaviour, as well as in the pathobiology of mood disorders (Halbreich & Kahn, 2001). Furthermore, many of these studies ignored the fact that oestrogen and progesterone play a key role in attaining positive moods by re-uptake of serotonin (Suser & Hermann, 2017). The physical condition of a woman does not depend on the absolute blood level of her sex hormones, but on their relationship with each other. In the first half of the menstrual cycle, oestrogen plays the main role, and after ovulation, progesterone. The oestrogen dominance in phases of low progesterone production causes puberty and premenstrual syndrome (PMS). At the beginning of the menopause, progesterone first decreases, leading to oestrogen dominance, and only later oestrogen decreases. Oestrogen is more potent through progesterone deficiency, even when produced in low quantities. Physically, oestrogen dominance may lead to headache, breast tension, weight gain, water retention, swollen feet, food cravings, insomnia, dizziness, hot flashes, and cycle disorders. Mental mood swings (irritability, anxiety, depression), lack of libido and listlessness with inner restlessness are found (Kasten, 2010; Suser & Hermann, 2017).

Thus, additional studies that investigate the differences between (1) vegans, (2) vegetarians and (3) omnivores are needed, particularly controlling for oestrogen levels. The present study analysed both eating habits and oestrogen levels (indirectly, via menstrual cycle data) for female participants. The goal of the study was to investigate the effects of nutrition on life-satisfaction when controlled for oestrogen levels.

Methods

The participants(N=65) were randomly chosen from a population in different parts of the European as well as from the Asian side of Istanbul (Turkey). The minimum age was 16 and the maximum was 53 years (M = 27.4, SD = 7.6). The participants were randomly selected, and they were asked to fill out the “Oxford Happiness Questionnaire”. Table 1 shows the frequency of the nutrition styles.

Table 1: Frequency of nutrition styles among sample women.

	Omnivore	Vegetarian	Vegan	Total
Female	45 (69.2%)	13 (20.0%)	7 (10.8%)	65 (100%)

The investigation was performed as an internet-based online questionnaire. The first items of the questionnaire asked for basic demographic information (age, gender), and whether the participants were (a) vegan, (b) vegetarian or (c) omnivore. All participants had followed their diet for at least six months. Female participants were also asked to report the date of their last period. While the first ten days of the follicular phase has a high level of oestrogen, the last days of the menstrual cycle (luteal phase) is characterized by low oestrogen levels. All participants were asked if they had any menstrual irregularities or were on pills. If they ticked either of these questions as yes, they were excluded from the sample. All subjects were regularly menstruating and none were pregnant, breastfeeding or suffered from a hormonal disorder.

The *Oxford Happiness Questionnaire* (Hills & Argyle, 2002) is comprised of 29 items, each presented as a single statement which can be endorsed on a uniform six-point Likert scale. The instrument is compact, easy to administer and allows level of agreement over an extended range. Sequential orthogonal factor analyses of the OHQ identified a single higher order factor, which suggests that the construct of well-being it measures is uni-dimensional. Items included were e.g.: *I am intensely interested in other people. I feel that life is very rewarding. I have very warm feelings towards almost everyone. I laugh a lot. I am well satisfied about everything in my life. I often experience joy and elation. I feel I have a great deal of energy.* For the evaluation, the average of all 29 questions on the 6-step Likert scale was determined. Between 1 and 2 points was classified as “not happy”; between two and three somewhat unhappy. Between three and four was neutral – not really happy or unhappy. A score of 3.5 reflects an equal number of happy and unhappy responses. An average of 4 points means moderately happy - satisfied. Between four and five was classed as moderately happy and between five and six very happy. 6 points was estimated as “too happy”, because research indicates that there is an ideal level of happiness, and that being too happy may be associated with poorer performance in several areas of daily life.

Results

A Pearson’s correlation test was conducted to test the influence of age. Results showed no significant correlation between age and life-satisfaction ($r=0.086$; $p= 0.418$). Therefore, the data were analysed as a whole, i.e. no subgroups were necessary.

Between the three styles of nutrition, only small differences were found. All groups achieved an average of more than 4 points, which lies in the range of moderately happy. The mean score over all three groups was 4.30 ±0.84. The difference between the omnivore (4.23 ±0.69) and the vegetarian group (4.29 ±1.24) was very small, but the vegan group achieved a higher score (5.20 ±0.17; see Fig. 1). It should be noted that the vegan group consisted of only of n=7 participants.

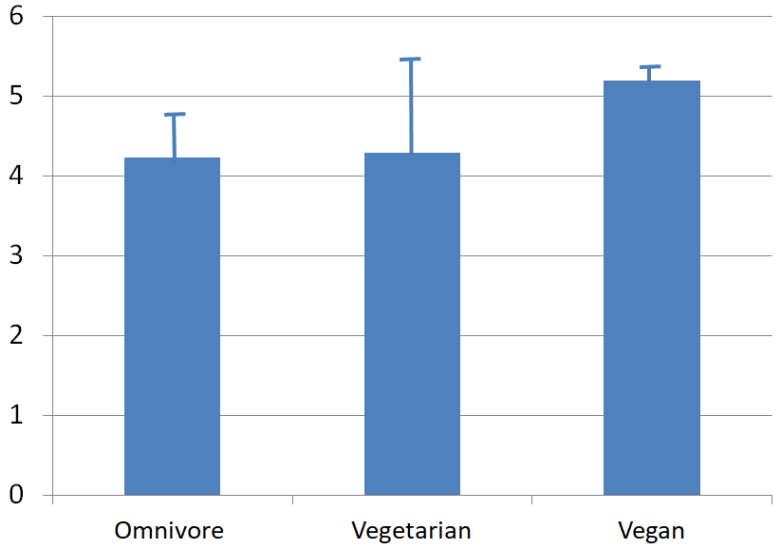

Fig. 1: Results of the *Oxford Happiness Questionnaire* for the three groups of nutrition-style on a 6-stepped Likert-scale (1 = not happy, 6 = very happy).

The estimated oestrogen level had significant effects on the result of the *Oxford Happiness Scale* (see Fig. 2). Women with low oestrogen level (mean =4.10) had the lowest scores on the happiness scale, in contrast to medium (mean =4.65) and high oestrogen levels (mean =4.5).

The main hypothesis of this project was that life satisfaction is influenced by the diet style of the participants when controlling for oestrogen level. To test this hypothesis an ANCOVA was performed. Results indicate that nutrition style has a marginally significant main effect on happiness [F (2,62) = 2.852; p=0.066] and that the oestrogen level has significant effects on satisfaction of everyday life [F (1,62) = 4.103; p=0.047].

Discussion

One possible explanation for why plant-based nutrition leads to increased happiness levels may be that it has always represented the major component of the human diet. Although a significant part of majority's diet consists of plant-based foods, they are often critical when they hear terms like "vegetarians" or "vegans." In 2015 Remesi Fardet wrote: *"Contrary to popular belief, many early human food cultures were plant-based. History shows that rising population living standards so far have resulted in an increase in the consumption of animal products. In Western countries, this has now become very high. For example, nearly one-third of the dietary energy consumed in France is of animal origin."* And: *"… people seem sceptical about vegetarianism. (Meaning, not eating meat –red meat, poultry, seafood and the flesh of any other animal –a stricter version of which is also avoidance of by-products of animal slaughter). But the respective share of animal and plant products in the human diet is now of paramount importance, to ensure adequate food availability for a fast-growing global population, to optimize the relationship between diet and health, and to reduce the ecological impact of agriculture and livestock."*

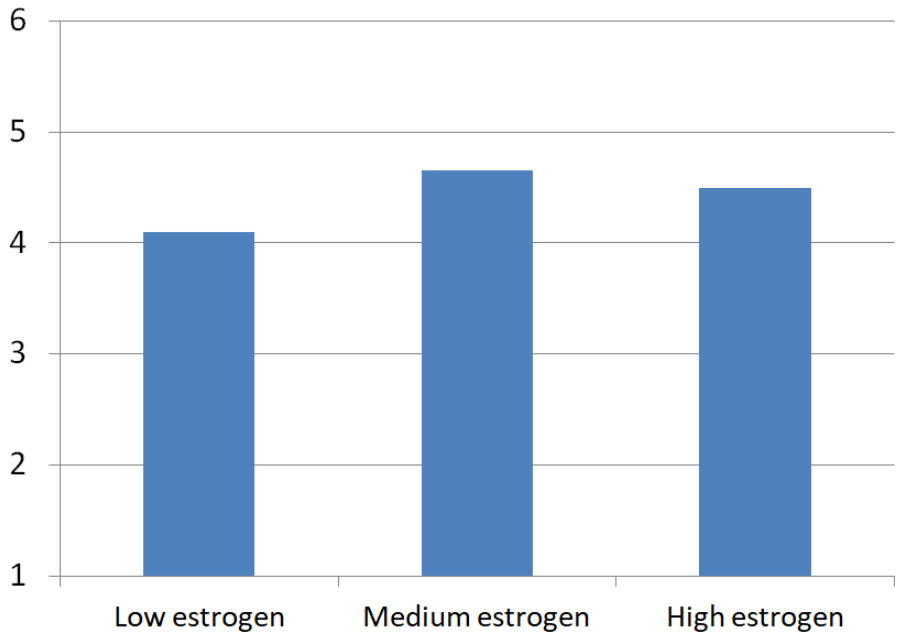

Fig. 2: Differences of the oestrogen level (estimated from the distance from the last menstruation) on the results of the *Oxford Happiness Questionnaire* (1 = not happy, 6 = very happy).

The results of this pilot-study suggest that nutrition style may have an effect on the level of satisfaction in everyday life. Vegans showed the highest scores followed by vegetarians and omnivores, which were nearly equal. Estimated oestrogen level and happiness were found to be significantly and positively associated.

One of the limitations of the study presented here was the small sample size, especially in the vegan group. In addition, it would be preferable to check the oestrogen level with at least a minimum of two measurement points of the same participant. In this study, only one measurement point was taken into account and the participants were then assigned to one of the three groups of the menstrual cycle. Here, in some women, the premenstrual syndrome, which is often associated with strong mood swings, would have affected the data. Another problem of this study was that the number of years of being a vegan or vegetarian was not taken in the account; participants were asked only for the last half year. A longitudinal study with a control-group would better test the hypothesis.

However, other data support positive effects of a plant-based diet on somatic and psychic health. Forestell and Neslek (2018) investigated whether vegetarians and omnivores differ in their personality characteristics. The authors used the five-factor model of personality and investigated depressive symptoms in vegetarians, who avoided meat and fish (n = 276); semi-vegetarians, who ate some meat and/or fish (n = 1,191); and omnivores (n = 4,955). Vegetarians and semi-vegetarians were more open to new experiences. Neither conscientiousness nor agreeableness varied as a function of dietary habits.

Jansen and co-authors (2016) state that the number of consumers following a vegan diet has notably increased in many industrialized countries and it is likely that their influence on the food sector will continue to grow. In a sample of German consumers, they found three main motives for adopting a vegan diet: Animal-related motives (mentioned by 89.7% of the respondents), motives related to personal well-being and/or health (69.3%), and environment-

related motives (46.8%). The results of the *Oxford Happiness Questionnaire* reported here support the hope of increased well-being.

However, people who favour the adoption of a vegan life-style should be aware that this requires significant knowledge and experience. The human body needs many substances that are often found largely in animal products. It is important to include adequate amounts of these substances in a plant-based diet. Hibbeln et al (2018) investigated 9,668 adult males in the Avon Longitudinal Study of Parents and Children, which included identification as vegetarian or vegan. Interestingly, vegetarian men had more depressive symptoms after adjustment for socio-demographic factors. Nutritional deficiencies (e.g. cobalamin or iron) are a possible explanation for these findings.

Null and co-authors (2017) explored how an intervention of diet and lifestyle, including a vegan diet, fruit and vegetable juices, nutritional supplements, regular exercise, and de-stressing techniques, would affect 27 subjects with anxiety, depression, poor memory, dementia, Alzheimer's disease, Parkinson's disease, history of stroke, or multiple sclerosis. The intervention appeared to provide considerable benefits for all the conditions addressed.

Of course, a vegan diet alone cannot be a guarantee for a happy life. Ultimately, the feeling of well-being results from many factors. Exercise, having little stress, being in a satisfying relationship, having a regular schedule and a satisfying job with a good financial position, all have a positive influence. Positive social contacts with many friends and adequate free time are essential ingredients (Antonosvsky, 1991, 1996). As the results of the study show, the menstrual cycle also has a major influence on mood. A healthy diet is the icing on this cake.

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