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Efficacy of the natural antioxidant astaxanthin in the treatment of functional dyspepsia in patients with or without *Helicobacter pylori* infection: A prospective, randomized, double blind, and placebo-controlled study

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Abstract

Objectives: The aim of this study was to evaluate the efficacy of the natural antioxidant astaxanthin in functional dyspepsia in different doses and compared with placebo.

Design: The study was a controlled, prospective, randomized, and double blind trial.

Participants: Patients with functional dyspepsia, divided into three groups with 44 individuals in each group (placebo, 16 mg, or 40 mg astaxanthin, respectively).

Interventions: Participants were asked to accept gastroscopy before treatment, together with questionnaires: GSRS and SF-36. Urea breath test (UBT) was done before the treatment.

Main outcome: The primary objective was to test the hypothesis that the antioxidant astaxanthin at two doses regimens compared to placebo should ameliorate gastrointestinal discomfort measured as GSRS in patients with functional dyspepsia, who were either positive or negative for *Helicobacter pylori*, after 4 weeks of treatment.

Results: At the end of therapy (week 4) no difference between the three treatment groups was observed regarding mean Gastrointestinal Symptom Rating Scale (GSRS) scores of abdominal pain, indigestion and reflux syndromes. The same results were observed at the end of follow-up. However reduction of reflux syndrome before treatment to week 4 was significantly pronounced in the higher (40 mg) dose compared to the other treatment groups (16 mg and placebo, $p = 0.04$).

Conclusion: In general, no curative effect of astaxanthin was found in functional dyspepsia patients. Significantly greater reduction of reflux symptoms were detected in patients treated with the highest dose of the natural antioxidant astaxanthin. The response was more pronounced in *H. pylori*-infected patients.

Keywords: Prospective randomized; Double blind and placebo-controlled study; Antioxidant; Astaxanthin; Functional dyspepsia with and without *Helicobacter pylori*

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Introduction

Functional dyspepsia (FD) is defined as pain or discomfort localized in the upper abdominal region typically associated with symptoms such as bloating, heartburn, nausea and early satiety (Hammer and Talley, 1999; Talley et al., 1998, 1999a, b). The diagnosis is made in individuals for whom examination including endoscopy does not reveal any identifiable explanation of the symptoms. Gastroduodenal discomfort affects approximately a quarter of the world's population, with about 50% of these having no structural abnormalities that can cause symptoms (Kagevi et al., 1989).

Studies in Denmark, Ireland, England, Sweden, and Australia have shown a prevalence of *Helicobacter pylori* from 26% to 43%, with an increase in older age groups (Buckley et al., 1998; Lin et al., 1998; Milman et al., 1998; Stone et al., 1998). The prevalence is higher in Eastern Europe (Befrits et al., 1993; Dite et al., 1998). In Lithuania 70–80% of patients with functional dyspepsia are infected with *H. pylori* (Kiudelis et al., 2002). Although association of functional dyspepsia and *H. pylori* infection is not clearly defined, suppression of gastritis can play a role in amelioration of dyspeptic symptoms (Lazzaroni et al., 1996). A standard treatment for patients who suffers from these symptoms is not established (Agréus and Talley, 1997). Both Maastricht 2 and Maastricht 3 consensus (Malfertheiner et al., 2002, 2005) recommend to eradicate *H. pylori* for all patients with non-malignant diseases associated with this pathogen. However, its effect is variable, ranging from the highest benefit in the cure of peptic ulcer disease to a small benefit in patients with FD (Malfertheiner et al., 2002).

H. pylori infection has been associated with generation of reactive oxygen species (ROS) (Naito and Yoshikawa, 2002), which leads to oxidative stress in the gastric mucosa. *H. pylori* induces infiltration and activation of neutrophils, which produces inflammatory mediators that include ROS (Ernst, 1999). These mediators contribute to oxidative stress on the gastric epithelium in the immediate vicinity. A diet rich in antioxidants or the use of dietary supplements of antioxidants as chemoprevention against *H. pylori* infection have therefore received attention (Correa et al., 2000).

Astaxanthin (Fig. 1) is a naturally occurring carotenoid with strong antioxidant properties both *in vitro* and *in vivo* (Hussein et al., 2006). Studies in *H. pylori*-infected mice indicate that the carotenoid astaxanthin reduced oxidative stress (Wetscher et al., 1995) and subsequent effects on neutrophilic leukocytes and activated macrophages recruitment in the gastric mucosa (Bennedsen et al., 1999). Testing *H. pylori*-infected animals, treatment with astaxanthin was shown to reduce gastric inflammation and the bacterial load and

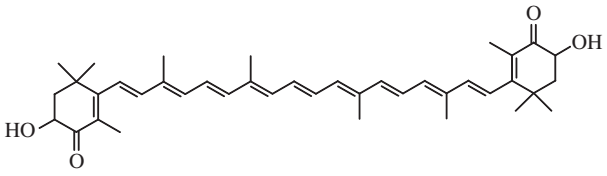

Fig. 1. Chemical structure of astaxanthin.

modulating cytokine release by splenocytes (Bennedsen et al., 1999). Both mechanisms play important roles in the chemotaxis of *H. pylori*, and hence, astaxanthin may influence *H. pylori's* role in the etiology of functional dyspepsia (Axon, 1994).

Ten patients tested astaxanthin in a pilot trial prior to this study (Lignell et al., 1999). All were *H. pylori* infected and showed typical symptoms of functional dyspepsia and functional dyspepsia-related symptoms that were reduced considerably by this treatment. Based on this tendency we undertook this trial to investigate the effect of astaxanthin.

Methods

Study objectives

The primary objective was to test if the antioxidant astaxanthin, with two dose levels compared to placebo, during 4 weeks, should ameliorate gastrointestinal discomfort, as measured by the Gastrointestinal Symptom Rating Scale (GSRS) score in patients with functional dyspepsia, who were either *H. pylori* positive or *H. pylori* negative.

Secondary objectives were to demonstrate safety after oral treatment with astaxanthin versus placebo when given twice daily for 4 weeks in patients with FD and to evaluate quality of life (QoL) according to the SF-36 Healthy Survey.

Patients

Males and females (non-lactating and non-pregnant) aged 18–70 years were included in the study. Symptoms of functional dyspepsia were defined as per the Rome II criteria: "The last 12 weeks, not necessarily consecutive, within the last 12 months, the patients should have experienced: persistent or recurrent dyspepsia as pain or discomfort centrally located in upper abdomen, and with no evidence of organic disease (including endoscopy findings) that could explain the symptoms, and no evidence that the dyspepsia was eased after defecation or was connected to a change in the consistence of the stool". Symptoms of heartburn and regurgitation were allowed within the spectrum of dyspepsia, but patients with predominant reflux symptoms were considered to

Table 1. Demographic data and *Helicobacter pylori* status of 131 participants at baseline according to treatment allocation

Characteristics	Astaxanthin (40 mg) group ($n = 44$)	Astaxanthin (16 mg) group ($n = 43$)	Placebo group ($n = 44$)
Sex (*n*)			
Male	5	4	9
Female	39	39	35
Mean (±S.D.) age (years)	45.7±11.9	42.9±13	43.2±14
Mean (±S.D.) weight (kg)	66±11.6	68.8±13.2	66.2±12.4
Helicobacter pylori status (*n*)			
Positive	26	29	26
Negative	18	14	17

have non-erosive gastroesophageal reflux disease (NERD) and were not included. Patients with clinically relevant abnormalities in physical examination or laboratory screening tests with a history of peptic ulcer and/or reflux-esophagitis at endoscopy or any evidence of significant hematological, hepatic, renal, cardiac, pulmonary, metabolic and other structural diseases were not included. Administration of any antibiotic, proton pump inhibitor, or bismuth salt, NSAIDs in the 30-day period before entry into the study were not allowed (Table 1).

Study design

This was a randomized, prospective, double blind, and placebo-controlled study with 132 patients with the diagnosis FD into three parallel treatment groups (44 patients per group). Patient recruitment was conducted from the Outpatient Department of Gastroenterology of the University Clinic, in Kaunas, Lithuania. After a screening period of up to 30 days the study duration was 8 weeks, comprising a 4-week treatment period and a 4-week post-treatment follow-up of efficacy and safety. Four visits to the study center were performed, at screening, weeks 0, 4, and 8. During the screening period a gastroscopy was performed in order to exclude organic disease. Urea breath test for diagnosis of *H. pylori* infection was done at week 0. Gastrointestinal symptoms as measured by the validated questionnaire GSRS (Dimenäs et al., 1996; Junghard et al., 1998) were assessed at weeks 0, 4, and 8 and QoL, in terms of the SF-36 Health Survey, were assessed at the same time periods. Safety was evaluated in terms of severe to mild adverse events, physical examinations and clinical laboratory tests at weeks 0, 4, and 8. GSRS scoring reflects the patient's experience of the dyspepsia symptoms during the preceding week: pain, heartburn, acid reflux, hunger, pain, nausea, stomach rumbles, stomach swelling, belching, bloating, constipation, diarrhea, and interchange between constipation and diarrhea. The primary efficacy variable was the GSRS score after 4 weeks of treatment. The primary comparisons were performed between treatment with 16 mg/day of astaxanthin and placebo and between treatment with 40 mg/day of astaxanthin and placebo. The aim of the SF-36 questionnaire is to measure the state of health of the patient, general impression of their health and capacity to perform work including everyday activities.

The urea breath test "Helicobacter Test HP-PLUS R" (Utandningstester i Sverige AB, Göteborg, Sweden) was done before treatment. The patients performed the urea breath test according to the instructions from the manufacturer. The patients were fasting for at least 6 h before the test. The test was not to be used until after at least 4 weeks without any antibiotic therapy and last dose of acid antisecretory agents.

Determination of sample size

It was calculated that a sample size of 132 (44 patients per treatment group), was sufficient to detect a difference of 1.25 points/degrees per item (in total 18.75) in the dyspeptic symptom score, with a power of 80%, a 5% significance level adjusted for multiplicity, assuming a standard deviation of 26, and a 10% drop out rate.

A total of 132 patients were thus to be recruited, 44 patients in each treatment group. It was anticipated that 120 patients would complete the study, 40 patients in each treatment group.

Treatments arms

After the screening period and gastroscopy, patients were randomized into one of three treatment groups:

Group 1—placebo: 5 capsules placebo twice daily.
Group 2–16 mg astaxanthin: 5 capsules twice daily.
Group 3–40 mg astaxanthin: 5 capsules twice daily.

The source of astaxanthin was homogenized and spray dried cells of the unicellular green alga *Haematococcus pluvialis* (AstaCarox® by AstaReal AB, Gustavsberg, Sweden). The astaxanthin content was 3.5% w/w in the alga meal. Dextrin was used as an exhibit and it

was the sole component in the placebo capsules. The capsulation in identical looking hard gelatin capsules was done by Napro Pharma, Brattvag, Norway.

The medication was given twice daily during a 4-week treatment period. The patients were allocated to each treatment arm on the basis of a consecutive randomization schedule. The patient number assigned corresponded to the treatment given and also appeared on the medication container and ran through numbers 001–132. Patients were randomized to one of the three arms (placebo, astaxanthin 16 mg/day and astaxanthin 40 mg/day) using a computer-generated random list with permuted blocks. The study was approved by the Research Ethics Review Board at Kaunas University of Medicine (No. 19/2000).

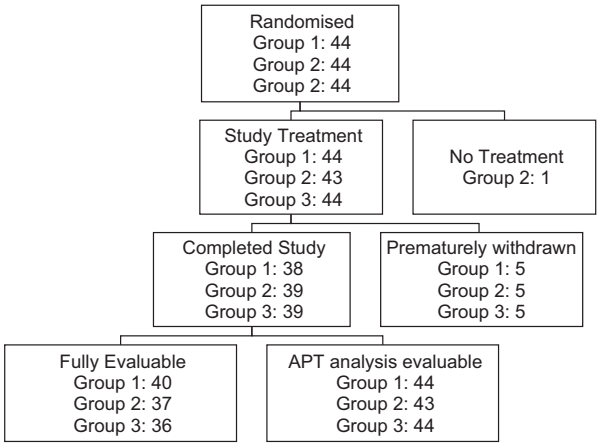

Fig. 2. Disposition of patients (*n*) through trial.

Treatment compliance

Subjects were instructed to bring their study medication to every visit. Compliance was assessed and recorded by counting capsules left in the packet after the treatment, i.e. at week 4, and expressed in percent. To be included in the per-protocol analysis of the efficacy assessment, at least 80% of capsules had to be taken by the patient. It is assumed that the patients complied with the dosing instructions provided by the investigator.

Statistics

Two principles of statistical analysis of efficacy were used: (1) an all patients treated (APT, all patients randomized) or (2) a per-protocol (PP, all patients completing the protocol) analysis. The APT analysis was used for the primary analysis of efficacy variables and included every patient randomized. The PP analysis included all patients that completed the entire protocol. For GSRS, the null hypothesis was equal treatment effect in the treatment groups. The alternative hypothesis was a difference between at least two of the treatments. The primary efficacy variable, the GSRS after 4 weeks of treatment, was analyzed by the Kruskal–Wallis non-parametric one-way analysis of variance. If the null hypothesis was rejected, pair-wise comparisons were performed between placebo and 16-mg/day astaxanthin treatment groups, between placebo and the 40-mg/day astaxanthin treatment group and between the two active treatment groups using the Wilcoxon–Mann–Whitney test. Adjustment for multiplicity was to be done by the Bonferroni–Holm method to keep the significance level at 5%.

Results

One hundred and thirty-two patients were included in the study (Fig. 2). One patient dropped out in the screening period, thus 131 patients were available for APT analysis. Patients in different treatment groups did not differ significantly regarding demographic characteristics and *H. pylori* status (Table 1).

Change of dyspeptic symptoms

Gastrointestinal symptoms were measured after 4 weeks of treatment and at follow-up after further 4 weeks (ATP analysis). Since GSRS consists of several different variables it was decided to further evaluate abdominal pain syndrome, indigestion syndrome and reflux syndrome as the primary variable. The symptom scores of all three variables decreased in all treatment groups from baseline to end of treatment and at follow-up, showing a prominent placebo effect (Table 2). At the end of therapy (week 4) no difference between the three treatment groups was observed regarding mean GSRS scores of abdominal pain, indigestion and reflux syndromes. Therefore the primary hypothesis that the antioxidant astaxanthin compared to placebo during 4 weeks, will ameliorate gastrointestinal discomfort as measured by the GSRS score, in patients with FD could not be proven. The same results were observed at the end of follow-up.

In addition the change from baseline to week 4 in all GSRS variables were analyzed with the APT analysis set. In these analyses the Kruskal–Wallis test showed a statistically significant difference between the different groups. A reduction of reflux syndrome from baseline to week 4 was significantly pronounced in the higher dose 40 mg group compared to other two treatment groups: AX 40 mg vs. AX 16 mg, $p = 0.0165$; AX 40 mg vs. placebo, $p = 0.0337$; and AX 16 mg vs. placebo, $p = 0.8409$. No significant differences of changes in GSRS scores were observed regarding other dyspeptic symptoms.

Table 2. Abdominal pain syndrome, indigestion syndrome, and reflux syndrome (mean of GSRS questionnaire scores) in patients at baseline, end of therapy (week 4), and end of follow-up (week 8)

Symptom patients		Mean ± S.D. of GSRS score		
Variable group		Baseline	End of therapy (week 4)	End of follow up (week 8)
Abdominal pain syndrome	Astax. 40 mg	2.82 ± 1.209	1.95 ± 0.777	2.03 ± 0.829
	Astax. 16 mg	3.40 ± 1.248	1.85 ± 0.716	2.20 ± 0.999
	Placebo	3.10 ± 0.996	1.87 ± 0.799	2.01 ± 0.873
Indigestion syndrome	Astax. 40 mg	2.87 ± 0.962	2.21 ± 0.979	1.85 ± 0.854
	Astax. 16 mg	2.09 ± 1.048	2.46 ± 1.091	1.88 ± 0.843
	Placebo	2.78 ± 1.028	2.21 ± 0.748	1.78 ± 0.965
Reflux syndrome	Astax. 40 mg	2,59 ± 1.326	1.46 ± 0.616	1.63 ± 0.792
	Astax. 16 mg	2,09 ± 1.048	1.76 ± 0.899	1.74 ± 1.063
	Placebo	2,37 ± 1.296	1.77 ± 0.852	1.78 ± 0.944

Table 3. Reflux syndrome (mean of GSRS questionnaire scores) of *Helicobacter pylori* positive patients at baseline, end of therapy (week 4), and end of follow-up (week 8)

Patients group	Mean ± SD of GSRS score		
	Baseline	End of therapy (week 4)	End of follow-up (week 8)
Astaxanthin 40 mg	2.61 ± 1.45	1.41 ± 0.61	1.5 ± 0.7
Astaxanthin 16 mg	2.27 ± 1.09	1.77 ± 0.92	1.62 ± 1.03
Placebo	2.66 ± 1.38	1.91 ± 0.89	1.93 ± 1.07
p	$p > 0.05$	$p = 0.04$[a]	$p > 0.05$

[a] –40 mg group vs. placebo.

Sub-group analysis of *H. pylori* positive and *H. pylori* negative patients

We analyzed the efficacy of AX separately in H. *pylori* positive and H. *pylori* negative sub-group, aiming at assessing differences in functional dyspepsia outcome, according to secondary objectives prospectively decided.

Mean GSRS score of reflux syndrome at the end of the therapy was significantly lower in astaxanthin 40 mg group compared to placebo in *H. pylori* positive patients ($p = 0.04$, Table 3), but not in the *H. pylori* negative patient group (Table 4). There was no significant difference comparing 40 mg vs. 16 mg groups, as for comparing 16 mg vs. placebo. Scores of abdominal pain and indigestion syndromes did not differ significantly at the end of the therapy.

Quality of life

Baseline values regarding SF 36 at baseline and after 4 weeks of therapy did not differ significantly between the groups. The hypotheses of equal treatment effect among the groups could not be rejected for any of the variables analyzed. Hence no pair-wise comparisons between treatment groups were performed.

In addition an analysis of the change from baseline to week 4 measurements was performed with the ATP analysis set. The Kruskal–Wallis test showed a statistically significant difference between the groups in this analysis for the health transition item. A significant improvement in health transition was pronounced in the 40 mg group compared to the other two groups: AX 40 mg vs. AX 16 mg, $p = 0.0281$; AX 40 mg vs. placebo, $p = 0.0124$; and AX 16 mg vs. placebo, $p = 0.9612$. No other significant differences were observed regarding other parameters measured in SF 36.

Safety and compliance

A total of 36 adverse events were recorded (Table 5). Six events were judged to be mild and possibly related to the study drug and 13 adverse events were judged to have a moderate intensity. Four adverse events were judged to be severe with a possible relationship to the study drug while two severe adverse events were judged to have a probable relationship to the study drug. These latter two events were diagnosed as stomach/abdominal pain. No significant difference in the prevalence of adverse events could be detected when comparing the treatment groups. One patient in the placebo group had

Table 4. Reflux syndrome (mean of GSRS questionnaire scores) of *Helicobacter pylori* negative patients at baseline, end of therapy (week 4), and end of follow-up (week 8)

Patients group	Mean ± SD of GSRS score		
	Baseline	End of therapy (week 4)	End of follow-up (week 8)
Astaxanthin 40 mg	2.55 ± 1.16	1.52 ± 0.62	1.81 ± 0.96
Astaxanthin 16 mg	1.85 ± 0.91	1.72 ± 0.87	2.00 ± 1.14
Placebo	2.02 ± 1.0	1.59 ± 0.77	1.60 ± 0.68
p	$p > 0.05$	$p > 0.05$	$p > 0.05$

Table 5. Summary of adverse events of 131 patients according to treatment allocation

Adverse events	Astaxanthin (40 mg) group ($n = 44$)	Astaxanthin (16 mg) group ($n = 43$)	Placebo group ($n = 44$)	Total ($n = 131$)
Number of adverse events	8	15	13	36
Number of patients with at least one adverse event	7	10	7	24

a serious adverse event-gastrointestinal hemorrhage. The event was considered not related to study drug as congenital thrombocytopathia was diagnosed in this case. No effects of the study treatment on laboratory values and vital signs were reported. If placebo levels are compared to 40 mg AX, fewer events took place in the highest dose group.

Patient's compliance was assessed as percentage of medication taken related to complete drug intake. APT analysis showed that more than 92% of medications were taken, while PP analysis demonstrated that more than 98% of medications were taken in each treatment group.

Discussion

This is the first randomized, prospective, double blind, placebo-controlled study of the antioxidant astaxanthin used for treatment of FD. The primary end-point was to study the effect of astaxanthin on dyspeptic symptoms and secondly to evaluate if astaxanthin is a safe treatment in patients with FD.

The results showed a prominent placebo effect on all dyspepsia symptoms. There is no gold standard for the management of functional dyspepsia. Usually different treatment options show comparable or slightly superior efficacy compared to placebo (de Grot GadB, 1997; Finney et al., 1998; Kupcinskas and Malfertheiner, 2005; Skuobo-Kristensen et al., 1989; Yeoh et al., 1997). Some meta-analysis have demonstrated positive effect over placebo (Dobrila et al., 1989). Proton pump inhibitors are only modestly superior to placebo to treat in ulcer-like, but not in dysmotility-like dyspepsia (Talley et al., 2001). *H. pylori* eradication therapy although is considered as standard treatment of *H. pylori*-associated functional dyspepsia, is able to achieve only 8–14% benefit over placebo (McColl et al., 1998; Moayyedi et al., 2005) or even does not show any benefit over placebo. Authors of the most comprehensive Cochrane Collaboration systematic review concluded that the number needed to cure one case of dyspepsia with *H. pylori* eradication was 18 (Moayyedi et al., 2005). The placebo effect in most clinical studies ranges from 6% to 62% (Moayyedi et al., 2005) and recently Madish et al. (2004) reported improvement of dyspeptic symptoms (according to Rome I criteria) in a randomized and placebo-controlled study evaluating a herbal preparation during 8 weeks of treatment. In our study the composition of the compound was standardized according to good manufacturing practice, and the study adhered to validated scientific methods with placebo control, blinding, etc. and the criteria used were also more strict following the Rome II definition. Prolonged treatment and/or higher dose might have resulted in more significant effect on dyspeptic symptoms.

No curative effect for astaxanthin treatment could be statistically supported by the result of this trial when comparing either the dyspepsia symptoms measured by GSRS score or QoL measured by SF 36 between the test groups at the end of the treatment. However, reduction of symptoms associated with acid reflux from baseline to end of treatment was significantly higher among patients receiving 40 mg of astaxanthin daily. There was also an indication of improved well being in this group, as

judged by the significant improvement in health transition item in SF 36 from baseline to end of treatment compared to the other two treatment groups. These findings are interesting and deserve further studies. The reduction in reflux symptoms was also the most pronounced result in an earlier open pilot study with astaxanthin treatment in *H. pylori* positive non-ulcer dyspeptic patients (Lignell et al., 1999). We did not include patients having purely reflux symptoms, thus heartburn and regurgitation were only concomitant complaints associated with other dyspeptic symptoms. This also reduces a possibility to demonstrate a positive effect on ''reflux dyspepsia'', which would have been the case if we had used Rome I criteria.

Reflux syndrome score at the end of therapy was significantly lower in *H. pylori* positive patients treated with the highest dose of astaxanthin than for those receiving placebo or a 16 mg daily dose. This threshold effect was not detected in *H. pylori* negative patients. Subgroups of patients were relatively small and the results should be interpreted with caution. Thus, there was a trend of better clinical effect in *H. pylori* positive patients. A previous 1-year prospective study from our group evaluating symptomatic and disease outcomes of duodenal ulcer patients, showed a marked decrease of reflux-associated symptoms after successful *H. pylori* eradication (Kupcinskas and Malfertheiner, 2005). We can only speculate that suppression of *H. pylori* by astaxanthin led to amelioration of reflux symptoms within the spectrum of functional dyspepsia. *H. pylori* infection causes oxidative stress that results in lower levels of vitamin C in gastric juice (Sobala et al., 1993). Rebepamide, a synthetic gastroprotective agent with antioxidant properties, inhibits *H. pylori* gastritis, and is effective in reducing belching in *H. pylori* positive, but not in *H. pylori* negative, FD patients compared to placebo (Talley et al., 2001). Studies in mice model have shown that both vitamin C and astaxanthin supressed *H. pylori* infection and decreased lipoperoxidation measured in gastric biopsis (Wetscher et al., 1995). Astaxanthin also had an immunomodulation effect in the mice model by down regulating the Th1 response (4) triggered by the bacteria (Mohammadi et al., 1996). This over active Th1 response is regulated by activation of NF-κB (Mohamed et al., 2006). Activation of NF-κB by reactive oxygen species in both in vitro and in vivo has been shown to be inhibited by astaxanthin (Lee et al., 2003). Astaxanthin has furthermore been shown to protect gastric mucosa from ulceration by its antioxidant properties in animal models (Kim et al. 2005a, b; Nishikawa et al 2005). Oxidative stress in the esophagus is also important in the development of gastroesophagal reflux disease (Oh et al., 2001; Wetscher et al., 1995), Treatment of surgically induced esophagitis in rats with the antioxidants rutin and harmaline inhibited lipid peroxidation and myeloperoxidase in the esophagus, in comparison with untreated rats (Shin et al., 2002). We can hypothesize that the stronger response in *H. pylori* positive patients is due to reduced oxidative stress in the stomach by the astaxanthin treatment and hence also less oxidative stress in esophagus resulting in ameliorated symptoms. This hypothesis has to be tested in further trials and the findings indicate that particularly studies aiming at assessing efficacy of astaxanthin on *H. pylori* gastritis and associated non-reflux disease would be of interest. Furthermore, reported rebound effects on discontinuation of proton pump inhibitors (Wang et al., 2000) could be worthwhile exploring with an antioxidative support during PPI treatment termination.

Astaxanthin in the present form is produced from the unicellular green alga *Haematococcus pluvialis* and is approved as food supplement. It was well tolerated and safe in both the high- and low-treatment doses (16 and 40 mg) and compliance of patients was acceptable. This study also shows that good clinical practice (GCP) is achievable within academic trials even without full commercial sponsorship. Further food supplements should be tested with validated scientific methods.

In summary, hypothesis that all treatment options have the same efficacy could not be rejected by our study. Therefore no curative effect for astaxanthin treatment could be statistically supported. However, significantly greater reduction of reflux syndrome was detected in patients treated with 40 mg astaxanthin daily and it was associated with better response in *H. pylori*-infected patients compared to non-*H. pylori*-infected patients. Additional data is needed to clarify these findings and to assess effect of astaxanthin on non-erosive GERD symptoms and *H. pylori* gastritis.

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Competing interest

Dr. Åke Lignell was the representative of the sponsor, AstaReal AB. Other authors declare that the answer to the question on competing interest is No and therefore have nothing to declare. No dependence from funders to researchers occurred.

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